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# CORAL REEFS OF THE WORLD

## Volume 2: Indian Ocean, Red Sea and Gulf

## UNEP

The **United Nations Environment Programme (UNEP)** is a Secretariat within the United Nations which has been charged with the responsibility of working with Governments to catalyze the most sound forms of development, and to co-ordinate global action for development without destruction.

The **Regional Seas Programme** was initiated by UNEP in 1974. Since then the Governing Council of UNEP has repeatedly endorsed a regional approach to the control of marine pollution and the management of marine and coastal resources and has requested the development of regional action plans.

The Regional Seas Programme at present includes ten regions* and has over 120 coastal States participating in it. Each regional action plan is formulated according to the needs of the region as perceived by the Governments concerned, and is designed to link assessment of the quality of the marine environment, and of the causes of its deterioration, with activities for the management and development of the marine and coastal environment. The action plans promote the parallel development of regional legal agreements and of action-oriented programme activities**.

## IUCN

**The International Union for Conservation of Nature and Natural Resources (IUCN)** is a membership organization comprising governments, non-governmental organizations (NGOs), research institutions, and conservation agencies, whose objective is to promote and encourage the protection and sustainable use of living resources.

Founded in 1948, IUCN has nearly 600 members representing 116 countries. Its six Commissions comprise a global network of experts on threatened species, protected areas, ecology, environmental planning, environmental law, and environmental education. Its thematic programmes include tropical forests, wetlands, marine ecosystems, plants, oceanic islands, the Sahel, Antarctica, and population and sustainable development.

The **Conservation Monitoring Centre (CMC)** is the division of IUCN that provides an information service to the Union, its members, and the conservation and development communities. CMC has developed an integrated and cross-referenced global database on animals, plants and habitats of conservation concern, on protected areas throughout the world, and on the international trade in wildlife species and products. CMC produces a wide variety of specialist outputs and reports based on the analysis of this data, including such major publications as the Red Data Books and Protected Areas Directories which are now recognized as the authoritative reference works in their field.

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*Mediterranean Region, Kuwait Action Plan Region, West and Central African Region, Wider Caribbean Region, East Asian Seas Region, South-East Pacific Region, South Pacific Region, Red Sea and Gulf of Aden Region, Eastern African Region and South Asian Seas Region.

**UNEP: Achievements and planned development of UNEP's Regional Seas Programme and comparable programmes sponsored by other bodies. UNEP Regional Seas Reports and Studies No. 1 UNEP, 1982.

# CORAL REEFS OF THE WORLD

## Volume 2: Indian Ocean, Red Sea and Gulf

Prepared by

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Cambridge, U.K.

in collaboration with

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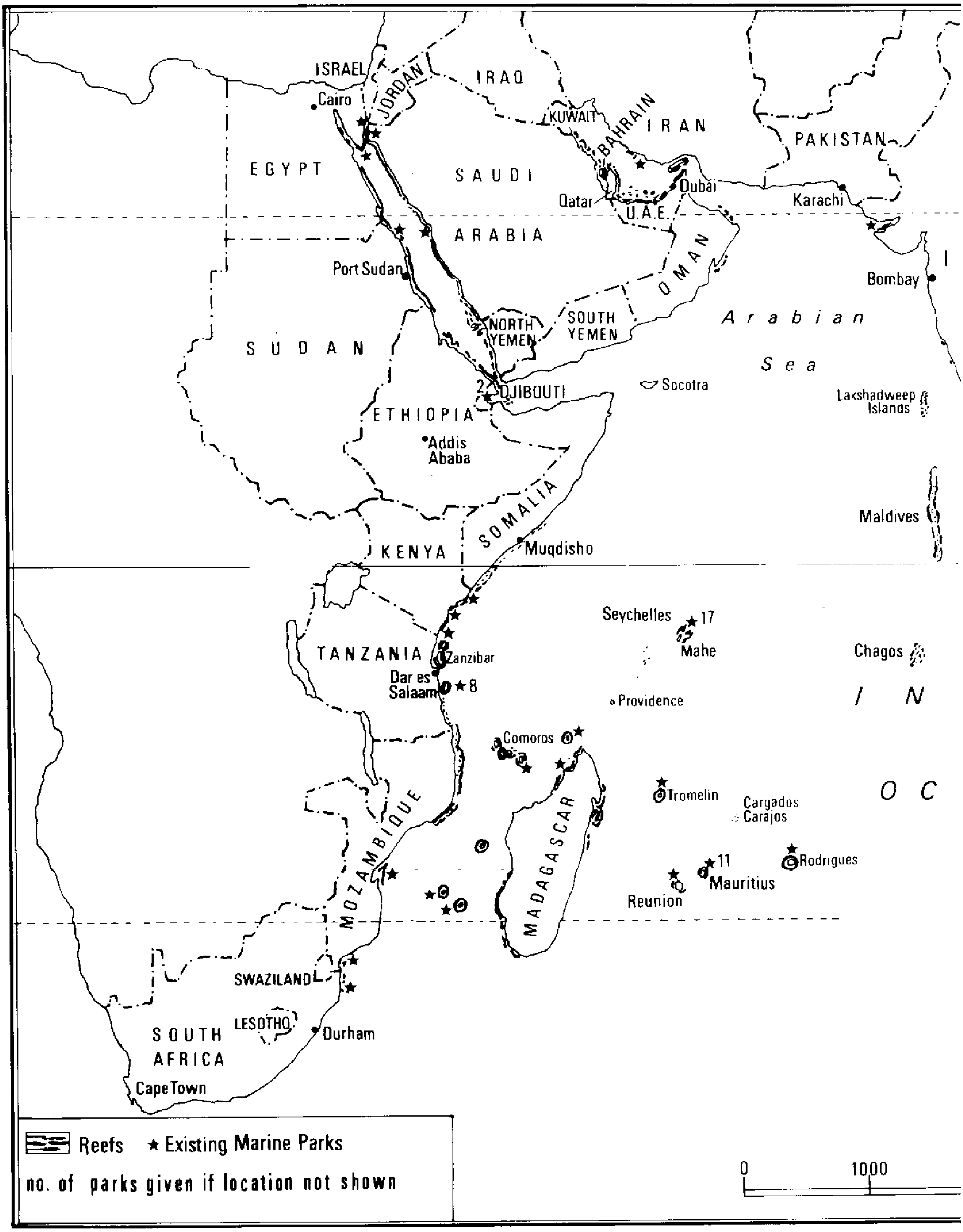
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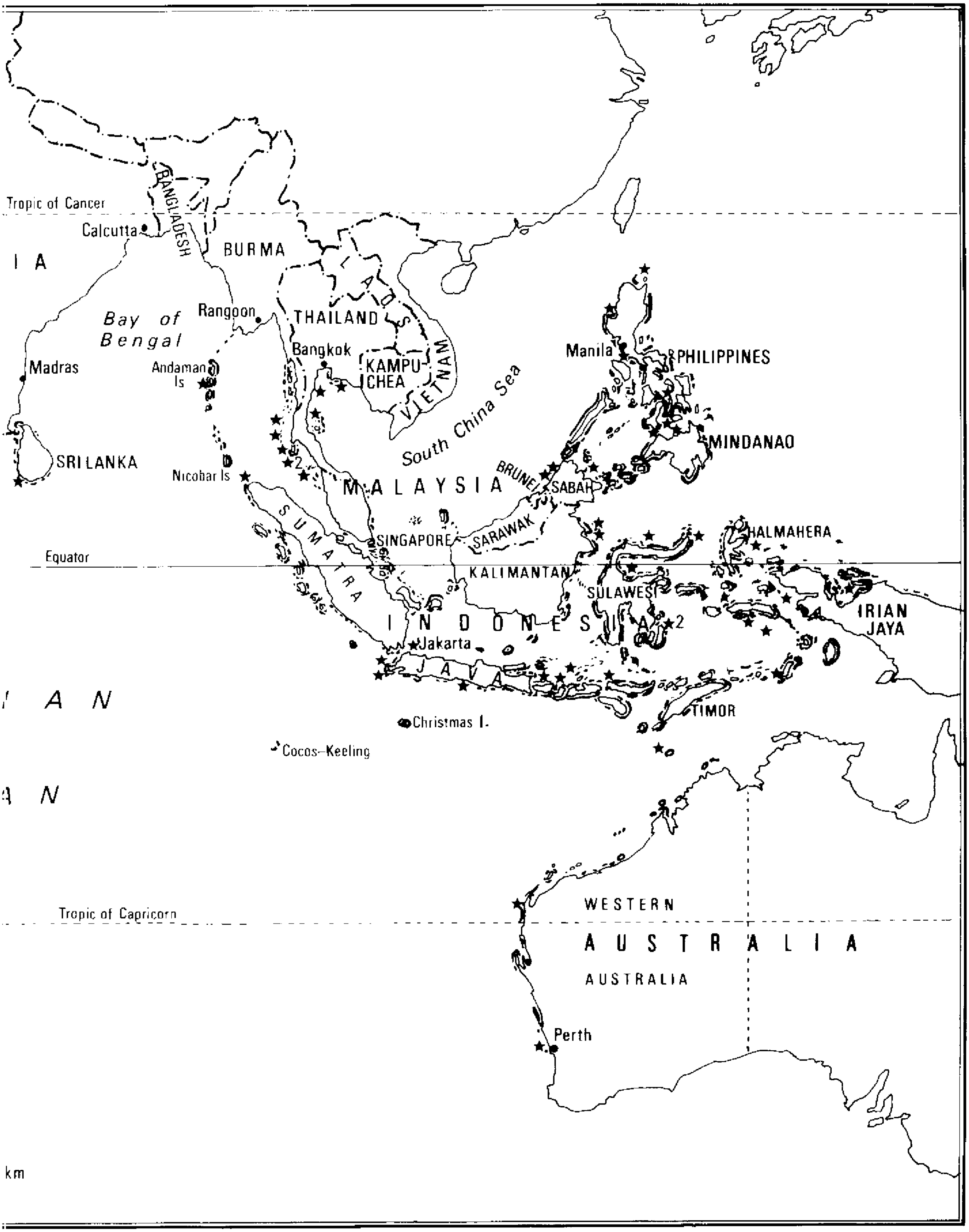

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# PREFACE

The last decade has seen growing concern for the future of coral reefs worldwide. Until comparatively recently, man used coral reefs for subsistence purposes only, as sources of food and craft materials. With the development of commercial fisheries, rapidly increasing populations still dependent on a subsistence lifestyle, growth of coastal ports and urban areas, increasing soil run-off due to deforestation and poor land use practices and most recently the exponential growth of coastal tourism, reefs have come under increasing pressure from both indirect and direct impacts. The theme 'The Reef and Man' was chosen for both the 4th and 5th International Coral Reef Congresses (1981 and 1985) when numerous papers were presented documenting the deterioration of reefs around the world. Reef protection and management were major issues at the 3rd World National Parks Congress, Bali in 1982 and at the XV Pacific Science Congress, Dunedin, New Zealand in 1983, and are now integrated into many environmental programmes and projects at international, regional and national levels.

Associated with this concern, there has been growing demand for information about coral reefs and their status. In response to this, the Coral Reef Working Group of the IUCN Commission on Ecology carried out two projects, one to document threats to reefs (see below) and a second to compile an inventory of parks and reserves containing coral reefs. The latter resulted in a preliminary list of coral reef protected areas, published in the IUCN Coral Reef Newsletters (Salvat, 1978, 1979, 1981 and 1982) which forms the basis of this Directory.

The aims of the Coral Reef Directory are:

1. to provide a broad survey of the reefs of the world giving sufficient detail to enable priorities for reef conservation to be established at both national and international levels.
2. to identify those areas where further research and conservation action is required.
3. to establish to what extent those reefs currently receiving or recommended for some form of protection are representative of the full range of reef types.
4. to promote more effective management of coral reefs by making basic information widely available.
5. to facilitate comparison between areas, thereby providing a working tool for those concerned with reef management.
6. to stimulate increased interest in coral reefs on the part of the general public, government officials, planners, scientists and students.

Many of the sections in this directory are incomplete and much of the information included will inevitably become rapidly out of date. However, the coral reef database at the IUCN Conservation Monitoring Centre in Cambridge will be continuously updated. Information should be sent to:

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# INTRODUCTION

## METHODS AND FORMAT

### Regional coverage

The Directory consists of three volumes covering 1) the Wider Caribbean, Atlantic and Eastern Pacific, 2) the Indian Ocean (up to and including South-east Asia), the Red Sea and the "Gulf" (i.e. the body of water between Saudi Arabia and Iran, commonly referred to as the Arabian or Persian Gulf) and 3) the Pacific and Australasia. This volume (2) includes 41 countries in the region extending from the East African coast, Red Sea and Gulf, east to the Philippines, Indonesia and Western Australia within the Afrotropical and Indomalayan Realms as defined by Udvardy (1975) (Eastern Australia is covered in Volume 3).

Five of the regions defined by the UNEP Regional Seas Programme are covered. The Kuwait Action Plan (KAP) Region comprises eight countries: Iran, Iraq (no reefs), Kuwait, Saudi Arabia, Bahrain, Qatar, the United Arab Emirates (UAE) and the Sultanate of Oman. The Red Sea and Gulf of Aden Region comprises six countries: Jordan, Saudi Arabia, Sudan, Somalia, North Yemen and South Yemen. The Eastern African Region comprises the Comoros, Reunion, Kenya, Madagascar, Mauritius, Mozambique, Seychelles, Somalia and Tanzania. The South Asian Seas Region comprises Bangladesh, India, the Maldives, Pakistan and Sri Lanka. The East Asian Seas Region comprises Thailand, Malaysia, Singapore, Indonesia and the Philippines. Western Australia, Burma, Chagos, Djibouti, Egypt, Ethiopia, Israel, South Africa and Vietnam are not in the Regional Seas Programme.

### Sources of information

Information has been obtained from a wide variety of sources, including published and unpublished material, and from a worldwide correspondence with coral reef researchers, conservationists and government officials. However, there are many gaps, either because the information is not available or because it has not been possible to contact the person who could provide it.

Accounts for protected areas which have been prepared for the IUCN Directory of Afrotropical Protected Areas (IUCN, 1987) and which are being compiled for the IUCN Directory of Indomalayan Protected Areas (IUCN, in prep.) have been rewritten in the appropriate format and additional information included where relevant; data on terrestrial aspects have generally been reduced. A recent source of information on marine parks is Silva *et al.* (1986) which provides an update on the list compiled by Björklund (1974). A complete and accurate listing of marine parks of the world is not yet available, partly because there are numerous instances where it is not known whether the park legislation covers marine (or submarine) habitat.

In order to keep the volume to a manageable size, coral reefs have had to be considered in isolation from other closely associated marine habitats, such as seagrass beds and mangroves. Directories of wetlands of international importance are currently being compiled for Africa by IUCN and UNEP and for Asia by IWRB (International Waterfowl Research Bureau) with the support of IUCN and UNEP. These will provide complementary volumes, with their emphasis on other coastal and marine habitats.

Information on reef-related species has been taken mainly from the IUCN Red Data Books, including Groombridge (1982) for turtles and crocodiles and Wells *et al.* (1983) for marine invertebrates. Information on seabirds is largely from papers in Croxall *et al.* (1984).

Maps showing the distribution of reefs and of proposed and established protected areas have been compiled for each country using, where possible, material sent in by correspondents and, where this was unavailable, British Admiralty Charts. In many instances, it was possible to give only a very rough approximation of true reef distribution and the extent of reef coverage is probably greatly under-represented.

### Site descriptions

The format has been adapted from that used in other IUCN directories. For each country, an introductory section describes the distribution of reefs within the country, their status, relevant conservation issues and legislation. A comprehensive reference list, including scientific monographs and papers, popular books and articles, bibliographies, management plans and unpublished reports, is included. This section is followed by detailed accounts for reefs already protected in national parks and reserves, reefs proposed for protection, and reefs recommended by qualified experts as requiring protection or management on the basis of their scientific interest or economic importance. These accounts have the following format:

1. *Geographical Location* province, region, geographical coordinates; where relevant the proximity to major towns, national borders, other protected areas and major features is noted.

2. *Area, Depth and Altitude* in hectares and metres: areas of both protected and unprotected areas; minimum/maximum depth of reef; altitude of associated cay/atoll/terrestrial ecosystem.

3. *Land Tenure* public (government-owned), freehold, private, etc., with percentages or hectarage where there is multiple ownership.

4. *Physical Features* topography, geology, climate, hydrology, and other physical features (e.g. salinity, water clarity, wave action, currents, water temperature), particularly as they affect management of the area; reef type e.g. barrier, fringing, atoll, patch.

5. *Reef Structure and Corals* reef zonation: coral morphology, diversity, per cent live cover and dominant species.

6. *Noteworthy Fauna and Flora* predominant algae and other vegetation; vertebrates and invertebrates which are of particular importance due to their dominance in the ecosystem, rarity, size of population, etc., in particular, species of possible economic importance (e.g. dugong, turtles, fish, molluscs, crustaceans, echinoderms, etc.) and those included in the IUCN Red Data Books.

7. *Scientific Importance and Research* importance of the reef in terms of the scientific interest of its coral formations and fauna; major research conducted in the area; details of current projects and scientific facilities.

8. *Economic and Social Benefits* use or potential use for fisheries (commercial or subsistence), tourism, recreation, mariculture, education, harbour protection.

9. *Disturbance or Deficiencies* siltation; pollution; damaging fishing methods (e.g. explosives, poisons, trawling); collection of corals for the curio trade, lime or building materials; overcollection of shells and other marine invertebrates; overfishing of reef fish for food or the aquarium trade; anchor damage and boat groundings; damage from tourists (e.g. trampling) and SCUBA divers; dredging, filling and other forms of coastal development.

10. *Legal Protection* degree of legal or special protection afforded to certain elements within the area.

11. *Management* local administrative entity for the area; presence of interpretative centres and wardens; degree of enforcement of legislation; system of zoning.

12. *Recommendations* legislation and management required; research priorities.

## CORALS AND REEF DISTRIBUTION

### Structure of coral reefs

Coral reefs rank as among the most biologically productive and diverse of all natural ecosystems, their high productivity stemming from efficient biological recycling, high retention of nutrients and a structure which provides habitat for a vast array of other organisms. They are tropical, shallow water ecosystems, largely restricted to the area between the latitudes 30°N and 30°S. The exact areal extent of coral reefs in the world is unknown and extremely difficult to estimate. However, Smith (1978) has produced a figure of 600 000 sq. km for reefs to a depth of 30 m. About 60% of the world's reefs occur within the area covered by the Indian Ocean region (an estimated 73 600 000 sq. km, according to IUCN/UNEP (1985f)), about half of which are in the Indian Ocean, Red Sea and Gulf and half in the "Asiatic Mediterranean", an area bounded by Indonesia to the west, northern Australia to the south, the Philippines to the east and mainland Asia to the north (Smith, 1978). General descriptions of coral reefs, their ecology and environmental requirements are given in Bemert and Ormond (1981), Wood (1983), Salm and Clark (1984), Kenchington and Hudson (1984) and Snedaker and Getter (1985).

The true reef-building corals (hermatypic or stony corals) are animals (polyps) that collectively deposit calcium carbonate to build colonies. The coral polyps have symbiotic algae (zooxanthellae) within their tissues which process the polyp's waste products, thus retaining vital nutrients. The term "reef" is used in the directory for a population of stony corals which continues to build on products of its own making (Stoddart, 1969). Not all reefs are constructed predominantly of corals. In particular, several genera of red algae grow as heavily calcified encrustations which bind the reef framework together, forming structures such as algal ridges. In other cases, populations of corals exist, often in deeper, colder waters, which either do not build on themselves or are formed of ahermatypic, non-symbiotic corals which do not build reefs. Many of these have been included in the directory (like true reefs they may also have a very high productivity) and have been termed coral assemblages or communities.

Present day reefs fall into two basic categories: shelf reefs, which form on the continental shelf of large land masses; and oceanic reefs, which develop adjacent to deeper waters, often in association with oceanic islands. Within these two categories are a number of different reef types: fringing reefs which grow close to shore (i.e. most shelf reefs, although some develop around oceanic islands); patch reefs which form on irregularities on shallow parts of the sea bed; bank reefs which occur deeper than patch reefs, both on the continental shelf and in oceanic waters; barrier reefs which develop along the edge of the continental shelf or through land subsidence in deeper water and are separated from the mainland or island by a relatively deep, wide lagoon; and atolls, which are roughly circular reefs around a central lagoon and are typically found in oceanic waters, probably corresponding to the fringing reefs of long since submerged islands.

The history of marine and reef-related research in the Indian Ocean is reviewed by Scheer (1984), and Morgan and Valencia (1983) give a brief account for South-east Asia. Early reef studies included those of Darwin (1842), Gardiner (1903-6 and 1936) and Sewell (1935). Further information was obtained between 1959 and 1965 during the International Indian Ocean Expedition. Following the early reviews by Stoddart (1971 and 1973), there has been a rapid increase in reef research. The following summary of physical features and reef distribution of the region draws on material in the country sections and also on the overviews provided by IUCN/UNEP (1985a, b, c, d, e and f) for the UNEP Regional Seas Programme. Other overviews for specific regions include Gomez (1980 and 1981), Morgan and Valencia (1983), Salm and Halim (1984), Soegiarto (1978 and 1985), White (1984) and Yap and Gomez (1985) for the East Asian Region, UNEP (in prep. a) for the South Asian Region, Saad (1984) and Wong and Degens (1980) for the Red Sea, UN/Unesco/UNEP (1982), Bliss-Guest (1983), Kundaeli (1983), Salm (1983), UNEP (1982a and b) and IUCN/UNEP (1984) for the Eastern African Region and Peters and Lionnet (1973) for the Central Western Indian Ocean. Bibliographies for the marine environment of the KAP Region (UNEP, 1984a) and the South Asian Seas (UNEP, 1984c) provide additional sources of information. Zeitzchel (1973) gives general information on the biology of the region.

**Reef distribution**

Coral growth is optimal only within a fairly narrow range of water temperatures and salinities, and reef structure and development is influenced by other oceanogaphic factors such as currents and wave force. The monsoonal cycle of the Indian Ocean therefore exerts a major control on reef distribution. In the southern part of the region, the south-east trade winds predominate throughout the year, but are most vigorous in the middle. The northern part of the Ocean, including the East African coast, is dominated by the north-east monsoon from November to March, with north-easterly winds, and by the wetter south-west monsoon from April to October (Couper, 1983; Pathmarajah, 1982). In South-east Asia, the wettest time of year in the west is during the south-west monsoon (June-August) and in the centre and east during the north-east monsoon (December-February). Annual rainfall is generally high and may reach 5000 mm. The Gulf, Red Sea and Gulf of Aden fall outside the Indian Ocean monsoonal gyre and have climates which are essentially continental, with limited rainfall and high temperatures for most of the year although in the north, temperatures can be extremely low in winter. In the Red Sea, wind and rainfall is determined by the north-east monsoon in winter and the drier south-west monsoon in summer but is very low and variable. In the Gulf of Aden the high surrounding mountains decrease the influence of the south-west monsoon in summer so that the prevailing wind is north-west; for the rest of the year, the north-east monsoon causes easterly winds.

Cyclones, which can have a major impact on reefs (see below), are commonest in the south-west of the region, where they occur mainly in January. Although the north has fewer, many more reach populated areas, particularly the Philippines, occurring mainly in May and November. The Red Sea and Gulf rarely have cyclones, but strong thermally generated winds resulting from intense heat are very common and, in the Gulf, the shamal winds have important cooling effects in winter.

Surface currents of the Indian Ocean are dominated by a large anticyclonic subtropical gyre in the south and a reversing current system in the north. The southern gyre forms the South Equatorial Current in lower latitudes which flows west throughout the year. At Madagascar it divides to form the Mozambique Current, which flows south between Madagascar and East Africa, and the Madagascar Current, which flows south along the east Madagascar coast. These two currents join south of Madagascar to form the Alguhas Current. North of Madagascar, the South Equatorial Current becomes the East African Coastal Current which, during the south-west monsoon, flows north to become the Somali Current; in the north-east monsoon there is an eastward flowing current, the Equatorial Countercurrent, at this latitude.

In the north of the Indian Ocean, currents reverses under the influence of the monsoons. In the north-east monsoon, the North Equatorial Current (Indian North-east Monsoon Drift) flows west to produce the south-west-flowing Somali Current off the coast of Somalia. In the south-west monsoon, from March to October, the Indian South-west Monsoon Drift flows east with branches flowing clockwise in both the Bay of Bengal and Arabian Sea. The latter, combined with the northerly-flowing Somali Current, results in major nutrient-rich, low-salinity, cool upwellings off Somalia and southern Oman, which also influence the Gulf of Aden, and which restrict coral growth (Fagoonee, 1983). The Gulf, Arabian Sea, Red Sea and Bay of Bengal have smaller scale and rather irregular circulations of their own. Many of the Red Sea and Gulf currents are ill-defined and are driven by wind or salinity gradients. In the Red Sea, low salinity water travels north up the east coast, increasing in density due to evaporation and mixing with subsurface water, and then returns down the west coast. At Bab el Mandab there is a shallow sill which limits the influence of the Indian Ocean. Deep currents are also important to reef distribution. At least two northerly streams flow up both sides of the Indian Ocean from sources in the Antarctic region and are deflected back towards the central Indian Ocean near or north of the Equator, the western stream contributing to the upwellings off Somalia.

South-east Asian waters are considered to be part of the Pacific Ocean. The North Equatorial Current from the Pacific splits into the northern Kuroshio Current and the southern Mindanao Current. During the north-east monsoon, currents flow from the north along the mainland coast of Asia and into South-east Asia; these are reversed in the south-west monsoon. Areas of upwelling have been reported to the north of Sumatra, off the south Javan coastline and in the Arafura Sea.

Surface temperatures over most of the Indian Ocean vary between 25°C and 30°C, with the western side generally warmer than the eastern side. Annual variation is small but increases off the East Afrcian coast, where the temperature drops in the south-west monsoon, and in the extreme north of the Bay of Bengal, Arabian Sea, Gulf of Aden, Red Sea and Gulf. In areas of upwelling, temperatures may be as low as 15°C. In the Gulf, temperatures may range from 10°C in winter to 35°C in summer, setting the area outside the optimum temperature range for corals. In the Red Sea, surface water temperatures range from 22°C in the north to 28°C in the south. Temperature variations in South-east Asian waters average 2°C but may be greater in the Banda, Arafura and Timor Seas in East Asia and in the waters south of Java and the China Sea, as a result of cold water moving through the Straits of Taiwan in the winter monsoon (Soegiarto, 1978).

Tidal range in the Indian Ocean is from 1 to 8 m. Throughout the oceanic islands and in southern India and Sri Lanka ranges are usually 2 m or less. Further north they increase gradually to 5 m, reaching at least 6 m in the Gulf of Kutch where currents of 2.5 m/sec are generated. The Bay of Bengal has semi-diurnal tides, while those in much of the rest of the region are mixed. The Red Sea and Gulf have very small tidal ranges. In the Gulf, in northern Kuwait, tidal range is 3.5-4 m but off Saudi Arabia it is less than 1 m. In the Red Sea, tidal range averages 0.5 m, with highest ranges at either end; tides are negligible at Port Sudan, Jiddah and just to the north of Bab-el-Mandab. In addition to diurnal tides there is a seasonal change in mean sea level which is higher in winter (Morcos, 1970). In South-east Asia, the semi-diurnal tides of the Indian Ocean predominate in the west, including the Andaman Sea, Straits of Malacca and off north-west Australia. Elsewhere, such as off the south coast of Sumatra, Java and Nusa Tenggara, there are mixed but prevailing semi-diurnal tides. The China

Sea has mixed prevailing diurnal tides and the Gulf of Thailand and Java Sea have almost pure diurnal tides.

Surface salinity in the Indian Ocean shows a clear gradient from greatest in the west (36-37 ppt in the Arabian Sea) to lowest in the east (30-33 ppt in the Bay of Bengal), owing to high rainfall and input of freshwater, especially during the south-west monsoon. Values may be lower locally, such as near the mouths of the Indus, Ganges and Irrawaddy. In the Red Sea, salinity rises gradually from 36-37 ppt in the Gulf of Aden to over 41 ppt in the north-west. The Gulf has abnormally high salinities, averaging 38.5-41 ppt in the north, and reaching 70 ppt at the southern end of the Gulf of Salwah. In South-east Asia, salinity is very variable but is usually within the requirements of corals and is related to the monsoons, but is often lower in mainland coastal waters.

**Red Sea reef distribution**

The Red Sea lies in an elongated depression and has a central trough which reaches depths of more than 2000 m but is absent from the Gulf of Suez and in the vicinity of Bab el Mandab. There is a terrace at 600-1000 m depth, and the continental shelf lies at 300-400 m depth or less and is variable in width. The Gulf of Suez is a wide, fairly shallow (maximum depth 85 m), basin dominated by sand and sediment with few corals or mangroves. The Gulf of Eilat or Aqaba is fairly deep, cold in winter and has varied sub-littoral ecosystems including coral reef areas with simplified zonation and community structures. It has two major marine basins, the northern one extending south to Nuweiba with depths of 1000 m; the southern one extending to Tiran with depths of 1800 m. There is usually exceptionally clear water as sediment tends to be trapped by the immense depth. The very small freshwater input from rivers or rainfall permits well-developed fringing reefs which are found semi-continuously along both coasts of the Red Sea proper but less in the southern portion; incomplete fringing reefs are found in inlets and partly enclosed bays. The comparative calmness and lack of severe storms mean that coral growth is less restricted by exposure to wave action than oceanic reefs, and some of their features, such as algal ridges and spur and groove systems, are greatly reduced.

The northern and central Red Sea has the best developed reefs. In the central sections reef complexes are found along the coast and at about 3-10 km offshore, having developed on a series of narrow underwater banks of tectonic origin. In the southern third of the Red Sea these banks are much wider and give rise to the Suakin, Dahlak and Farasan archipelagos, which may resemble atolls. Beyond the banks the sea bed drops rapidly to a stage at 500-1000+ m, from which occasional very steep-sided atoll-like pillar reefs may rise, often with impressive coral formations, for example Sanganeb and parts of the Farasan Bank. South of 20°N, there is a decrease in the quality, complexity and extent of reefs due to shallower bathymetry, higher turbidity and greater freshwater input. Little is known of the reefs in this area or of the reefs of the Gulf of Aden, which has a coastline similar to that of the Red Sea. Suitable substrates often tend to be dominated by algae, partly due to the influence of the upwellings. However, further work is showing that there are some good areas of reef in North and South Yemen and Somalia.

**Gulf reef distribution**

The KAP region covers the Inner Gulf, the Gulf of Oman and the part of the Arabian Sea which is bordered by Oman. The Gulf itself is an almost entirely enclosed and shallow sea, which slopes gently from the low and indented coastline of Saudi Arabia on the western shore to an elongated basin reaching 80-100 m depth close to the more linear and mountainous Iranian coast in the east. It covers an area of 226 000 sq. km (1000 km x 300 km) and has an average depth of 35 m, the deepest area (100-165 m) being near the Straits of Hormuz.

Reefs are less well-developed than in the Red Sea as the Gulf provides a highly stressful environment for corals but they can be spectacular and support at least 500 species of plants and animals (Basson *et al.*, 1977). Reef-building corals do not occur in the north but are numerous in the shallow waters to the south-west, around the Saudi Arabian offshore islands, Kubbar Island in Kuwait, and the islands between the Straits of Hormuz and Iran. Reefs are also found in the coastal waters of the United Arab Emirates, on the east coasts of Bahrain and Qatar and along the coasts of the Gulf of Oman. High salinities prevent their formation in the Gulfs of Bahrain and Salwah. The coastline of the Gulf of Aden and Arabian Sea is more like that of the Indian Ocean and represents a less stressful environment. However there are comparatively few reefs along the latter because of upwellings which contribute to the development of rich kelp communities (see section on Sultanate of Oman).

**Eastern African Region reefs**

Well developed fringing reefs and patch reef complexes occur along major sections of the fairly narrow continental shelf of Somalia, Kenya and Tanzania and around the offshore islands between 5°N and 20°S. They are broken only by large river outflows and are most extensive where the shelf broadens around islands. Madagascar and the Comoros have some well-developed reefs, including barrier reefs at Toliara on Madagascar and around Mayotte in the Comoros. The Seychelles Ridge supports the Seychelles Islands which are mainly granitic with small fringing reefs, although there are some limestone banks and coralline islands surrounded by reefs, and a few atolls such as Aldabra. The Saya de Malha Bank, Nazareth Bank and Cargados Carajos Shoals are large, partly or completely submerged, limestone plateaux, where reef structure and coral fauna remain largely unknown, although some of them, notably the Cargados Carajos Shoals, have exceptionally large algal ridges. In the Mascarene Islands, lying to the south and separated from each other by deep water, reef development decreases from east to west; Rodrigues and Mauritius have fairly extensive reefs unlike Réunion. The scattered islands of Tromelin, Europa, Bassas de India and Juan de Nova are little known but have some reef development. There appears to be little correlation between island type and extent of reef development in this region; for example, some high islands, such as Rodrigues, have good reef development but around others, such as Réunion and Mahé, reefs are relatively poor or absent.

### South Asian Region reefs

The northern Indian Ocean is divided by India into the Arabian Sea and the Bay of Bengal, both of which have areas of broad continental shelf but few offshore islands. Reef growth is inhibited by massive fresh water and sedimentary inputs from the Indus, Ganges and other smaller rivers and in the north-west by cold upwelling. India has two widely separated areas of reef development, in the north-west and south-east, and Sri Lanka has shallow fringing reefs and coral communities on sandstone outcrops along about half of its coastline. There are no reefs in Bangladesh and Pakistan due to high turbidity, although scattered coral communities may occur. On the eastern side of the Indian Ocean, fringing reefs are found on offshore islands and only rarely on the mainland coasts. The Andamans and Nicobars arise from a submerged mountain chain which follows a southward extension of the continental shelf and they have good reef development. The other main reef structures in this region are found in the atoll chain on the Laccadive-Chagos ridge, the Chagos group including a number of poorly known large submerged limestone banks.

### South-east Asian reefs

This region comprises the Andaman Sea, Straits of Malacca, China Sea, Java Sea, Flores Sea, Banda Sea, Arafura Sea, Timor Sea, Celebes Sea, Sulu Sea and Philippine Sea. The topography is complicated with shallow continental shelves, deep sea basins (the South China Sea being the largest), troughs, trenches and numerous coral and volcanic islands. Reefs are mainly fringing and are found around most small and medium-sized islands; on larger islands and mainland coasts, reefs are often absent particularly around river estuaries. Good reefs are found in the Mergui Archipelago in Burma and around the Andaman Sea coastal islets of Thailand. Coral growth in the Gulf of Thailand is limited by turbid waters but there are some reef areas, mostly in the east. The Vietnamese mainland coast supports few reefs, but some occur around offshore islands; they may also occur around islands off Kampuchea. Coastal islands off the east coast of Peninsula Malaysia have good reefs but there are few on the west coast; reef development is more extensive around the coast of Sabah.

The most extensive reef areas in the Indian Ocean are in Indonesia and the Philippines, which together have some 20 000 islands and the longest coastlines (some 81 000 km in Indonesia and 17 500 km in the Philippines). In Indonesia, there are extensive shallow areas of sea in the south and west on the Sunda Shelf, which is one of the largest continental shelves in the world, joining Sumatra, Java and Borneo to mainland Asia, with depths of 40-100 m (Soegiarto, 1978). Reefs are abundant along the southern rim, in the eastern archipelagos, in the Mentawai Archipelago, along many coasts in the Sunda Archipelago and in the Banda and Molucca Seas and Halmahera. Most Philippine coasts also have extensive reefs wherever mangroves are absent, especially in the more remote, smaller islands of the Sulu archipelago, off Palawan, in the central Visayas and on the Pacific coast.

### Coral diversity

About 77 hermatypic genera occur on reefs of the Indian Ocean. This number is very similar to the 79 recorded from Australia (Veron, 1986) and the 78 from the Philippines (Nemenzo, 1981). Regional patterns of diversity at generic level have been given by Rosen (1971) and updated by Scheer (1984). At species level, the regional patterns have been mapped by Sheppard (1987). Information is also provided by Stoddart (1984).

South-east Asia has the highest diversity at generic and especially at species level but, unlike the situation in the Pacific where diversity drops off markedly with distance from Australasia, in the Indian Ocean diversity falls only slightly, at least along the equatorial belt. This is in part because the western Indian Ocean has several species and genera which do not occur in the east. Many of the far eastern corals disappear with increasing distance westwards from Australasia just as they do to the east, though not nearly so markedly. However, in the westerly direction this loss is partly compensated by the appearance of many genera which are restricted to the African and Arabian coasts and to the island groups. Along the equatorial belt, therefore, net diversity remains remarkably constant, in marked contrast to the situation in the Pacific. At species level the effect is probably similar as far as is known (Veron, 1986; Sheppard, 1987) but the problem of synonymy precludes the use of accurate figures.

The "equatorial belt" referred to is, in the Indian Ocean, very broad. Partly because of the distribution of suitable substrates, a high diversity is maintained as far as the higher latitudes (for example on the southern African and Red Sea coasts) until suddenly a very rapid drop in diversity occurs over a short distance. This helps to create the impression of a uniform ocean in terms of coral diversity without the broadly spaced, regular steps which can be contoured for the Pacific.

Reefs of the Indian Ocean, like most others, may be dominated by *Acropora* or *Porites*, with members of the Pocilloporidae and Faviidae also being common, the former particularly in the shallows and the latter at mid depths.

Lists of coral species and genera for 24 countries or areas in this region are given in Sheppard (1987). For many of the countries or geographical areas included in this volume, insufficient work has been done for their inclusion in such a list, which illustrates the patchy nature of detailed work to date in many parts of the Indian Ocean.

## ECONOMIC IMPORTANCE OF REEFS

The World Conservation Strategy (IUCN/UNEP/WWF, 1980) identifies coral reefs as one of the "essential life-support systems" necessary for food production, health and other aspects of human survival and sustainable development. Reefs protect the coastline against waves and storm surge, prevent erosion and contribute to the formation of sandy beaches and sheltered harbours. They are a source of raw materials such as corals and coral sand for building materials, black coral for jewellery, and stony coral and shells for ornamental objects. Increasing numbers of reef species are being found to contain compounds with medical properties.

In many of the countries dealt with in this volume, the economy has traditionally been based on agriculture and fisheries. The Directory gives particular attention to the crucial role of reefs in fisheries and to their new role as a major focus of the tourist industry, owing to their aesthetic appeal and recreational value.

**Fisheries**

Reefs provide the fish, molluscs and crustaceans on which many coastal communities in developing countries depend and, with other coastal habitats, provide nutrients and breeding grounds for many commercial species. Overviews of the fisheries of the Indian Ocean region are given in IUCN/UNEP (1985 a, b, c, d, e, and f) and of South-east Asia in Morgan and Valencia (1983), and additional references may be found in individual country sections. Reefs are mainly important in small-scale traditional fisheries, particularly in island nations. Yields are often underestimated because of the large numbers of subsistence fishermen whose catches are not recorded, and are very variable (partly due to varying conditions under which estimates have been made), but it is thought that in general a sustainable yearly harvest of 15 t/sq. km can be obtained from coralline areas in depths of less than 30 m (Munro and Williams, 1985). In South-east Asia, where reef fisheries are particularly important, they have been the subject of considerable research. They have been estimated to make up 8-10% of the overall fishery production in the Philippines (where yields of up to 30 mt/sq. km have been estimated on reefs to 60 m depth), more than 20% in Sabah and 5% in Indonesia (see country sections for references). Reef fish are also taken for the aquarium trade in Indonesia, Mauritius, Maldives and Philippines. In the South-west Indian Ocean, reef fishing is moderately important for subsistence purposes on many of the islands (Ardill, 1983). Some of the limestone banks such as the Cargados Carajos Shoals, Nazareth and Saya da Malha are also important for commercial fishing. In the Gulf and Red Sea, reef fisheries are on a small scale, but artisanal handlining and potting for groupers and snappers are carried out and the reefs may be a refuge for some important commercial species. Fisheries in the Red Sea are described by El-Mahdy (1982).

In addition to finfish, a wide range of other species are taken including molluscs, crustaceans, turtles, corals, shells and algae (Ruddle, 1984; Gomez, 1980). Some reef invertebrates are collected for food, and are a major source of protein. Spiny lobsters are fished commercially in Somalia, India and Sri Lanka for export and are a major resource in the East Asian Region, and Oman, although here it is dependent as much on rocky habitat of the west coast as on coral reefs; small quantities of spiny lobsters are taken in the Red Sea.

The marine curio trade is also very important in a large number of countries. The Philippines is the centre of the coral and shell trade, with major industries based on mother-of-pearl and shellcraft, and corals and shells are exploited throughout much of South Asia and the Eastern African Region. There is a limited market for corals and shells in the Red Sea and the Gulf; mother-of-pearl used to be an important resource in the Red Sea but the fishery has declined.

**Tourism**

The tourist industry is developing rapidly and, although not yet as important overall as in the Caribbean, it is becoming of a major economic factor, particularly in island nations, where favourable climates, beaches, clear waters and reefs are major attractions. Tourism, much of it marine-related, is already the main foreign exchange earner in the Seychelles, and is of great significance in Mauritius, Réunion and the Maldives, and is soon to be developed in the Comoros. Reef-related tourism is developing in many of the larger countries such as Kenya, Sri Lanka, the Philippines, Indonesia and Thailand. In the Red Sea, it is already important in Israel, Egypt and Jordan; in Saudi Arabia and most of the Gulf countries it is not yet a major industry but recreational use of the reefs is increasing.

**VULNERABILITY OF REEFS**

Biological research on reefs in the 1960s and early 1970s led to the view that reefs were fragile ecosystems, particularly vulnerable to human activities and slow to recover if damaged (Johannes, 1975). Subsequent work led to contrasting ideas, that reef communities are dynamic and unstable and that self-replacement and recovery from natural disturbance is normal and contributes to the maintenance of high diversity on the reef (Connell, 1978). These theories have been reviewed by Pearson (1981), Brown and Howard (1985), Brown (1987) and Grigg and Dollar (in press), the consensus being that reefs are perhaps not as fragile as was previously thought.

However, corals generally have very specific requirements for light, temperature, water clarity, salinity and oxygen. Their lack of mobility makes them vulnerable to siltation, through smothering and oxygen depletion. Coral growth tends to be slower where sediments are regularly disturbed, and silted substrates inhibit larval settlement. Light penetration is decreased in turbid water, reducing photosynthesis by the symbiotic zooxanthellae; even in the clearest seas, reef-building corals are restricted to depths of less than 30 m and are generally found much shallower. Many stony corals have slow growth rates, which may be slowed further by adverse environmental conditions; Davies (1983) provides figures for reef growth in the range of 0.38-12 m per thousand years. Brown and Howard (1985) review the responses of corals to stress, in terms of altered growth rate and metabolism (photosynthesis and respiration), loss of zooxanthellae, behavioural responses such as filament extrusion and mucus production, sediment shedding, altered reproductive biology and the appearance of disease.

Hurricanes, storms, diseases and sea-level changes show that reefs are well adapted to recovery from a variety of sources of natural stress (Pearson, 1981), although the manner and speed with which this occurs may be immensely variable. Recovery rates have been estimated at from 20 to 50 years for complex reefs to only a few years for simpler reefs at a subclimax state of succession. Shallow water monospecific thickets of, for example, *Acropora palmata* may recover even more quickly (Grigg and Dollar, in press). There is some concern that such phenomena, particularly outbreaks of coral predators (see below), are occurring at increasing frequencies, perhaps as a result of human activities, although at present there is no general consensus of opinion (Brown, 1987). The observed increase in incidents may simply be an artefact of the rapid increase in reef studies over the last 20 years. Some of the more recent natural events in the Indian Ocean region are summarized in Table 1.

**Climatic, tidal and geological events**

Storms and cyclones can reduce large areas of reef to rubble through freshwater inundation and the breaking of branching corals. In East Asia, tsunamis occur although unlike similar events in the Caribbean they have not been studied. Storm surges caused by typhoons can also damage reefs (UNEP, in prep. b). Stoddart (1985) summarizes current thinking on the impact of storm damage; most research and the only long-term monitoring studies (on the impact of hurricanes) have been carried out in the Caribbean.

Cold temperatures periodically cause coral mortality in the more northerly parts of the region; elevated temperatures may be equally damaging, as in the Gulf and northern parts of the Red Sea. The abnormally high sea-water temperatures which accompanied the severe 1982-83 El Niño event, and were probably responsible for the widespread "bleaching" (i.e. loss of symbiotic zooxanthellae) and death of corals in the tropical Pacific and western Atlantic (Glynn, 1984), may also have contributed to similar mortalities in isolated areas in the Indian Ocean, such as Mayotte and islands off the north coast of Java (Table 1). It is thought that coral reef recovery may take many years or decades or decades in the Eastern Pacific; less information is available on similarly affected areas in the Indian Ocean.

Geological and tectonic events may affect reefs, for example in Indonesia where reefs in Nusa Tenggara have been affected by a volcanic eruption. Abnormally low tides have damaged reefs in several areas (see Table 1).

**Coral predators**

Coral predators may have a significant impact on reef structure and development. This is particularly evident in the Indo-Pacific, where outbreaks of the Crown-of-Thorns Starfish, *Acanthaster planci*, have affected many reefs (Table 1). This phenomenon has been less well studied in the Indian Ocean region than in the Pacific and on the Great Barrier Reef of Australia but populations have been monitored in Malaysia and Thailand and there are numerous reports of outbreaks. The gastropod *Drupella rugosa* has been reported to have damaged reefs in the Philippines, but this is the only reported outbreak of this species.

Sea urchins (particularly *Echinometra mathaei*, *Heterocentrotus mammillatus*, *Diadema setosum*, and *Tripneustes gratilla*) are common reef inhabitants in the region and, although not coral predators themselves, can cause significant damage if they occur in high numbers. They graze on algal turf on coral rock and through erosion of the rock surface may weaken the reef structure, as has been recorded in a number of countries (see Table 1). It is thought that urchin population outbreaks may be at least partially due to a decline in predators, such as pufferfish and triggerfish, caused by overfishing. Further discussion of this issue is given in the sections on Kenya and Egypt. The impact of coral predators and bioeroders is discussed by Hutchings (1986).

**Disease**

Two diseases, white band and black band, are widespread in the Caribbean but until recently had not been recorded in the Indo-Pacific. However, black band was reported in the Seychelles in the 1970s (see country section) and the Red Sea in the 1980s (Antonius, 1984). Coral genera and species differ in their response but the general effect is a weakening of the reef framework. These diseases do not appear to be correlated with human activities and may be caused by bacteria (Antonius, 1981; Peters, 1983; Gladfelter, 1982).

**HUMAN IMPACT ON REEFS**

Although reefs may be constantly experiencing natural change, there is increasing evidence that human impact, combined with natural disturbance, may significantly slow the recovery rate of a reef, particularly since man-induced damage is often chronic rather than temporary. Where reefs are of economic importance, their long recovery time may become an important issue. Kenchington and Hudson (1984), Salm and Clark (1984), Sorensen *et al.* (1984), Brown and Howard (1985), Salvat (in press) and Grigg and Dollar (in press) review the impact of human activities on coral reefs and Clark (1985) provides more detailed case studies.

Threats to coral reefs are intimately related to the high population densities of coastal areas. South-east Asia is one of the most populous regions in the world (Gomez, 1980) and the industrial centres of Malaysia, Indonesia and the Philippines all lie on the coast; Singapore is the most industrialized nation in the region and is entirely coastal. Population pressure on the coastal region is not quite so intense in other parts of the Indian Ocean but it is growing rapidly. Fringing reefs, lying immediately off shore, are particularly vulnerable to pollutants and sediments washed off the land and may be affected by activities taking place many miles away, such as deforestation. They also suffer greatest damage from overexploitation and recreational use owing to their accessibility. Atoll and barrier reefs are less vulnerable but may be affected by pollutants carried on oceanic currents or released from ships and, in areas which are important to fisheries, may be vulnerable to overexploitation.

As early as the 1930s, Gardiner (1936) expressed concern that reefs near human habitation in the Indian Ocean has declined in quality since his earlier studies in 1905. It has been estimated that 20% of the reefs in the Indian Ocean region have now been lost or seriously damaged (IUCN/UNEP, 1985f). The impact of current human activities on reefs in this region has been extensively reviewed, although compared with the Caribbean area, there are few scientific studies to document the extent of damage and potential for regeneration. Degradation of the reefs in the area is reviewed by Gomez (1980 and 1981), Yap and Gomez (1985), IUCN/UNEP (1984; 1985a, b, c, d, e and f), Ruddle (1984), White (1984), UNEP (1982a; in prep. a and b) and UN/Unesco/UNEP (1982). The main impacts on reefs in the region covered by this volume are discussed below and are listed in Table 2.

**Run-off from land clearance**

Soil run-off is the most frequent source of increased sediment content in coastal waters, which is considered to be one of the most damaging impacts on corals. It has been reported from 14 countries in the Indian Ocean region (Table 2) and is particularly serious on the East African coast (Finn, 1982 and 1983; O'Keefe, 1983; Randrianarijaona, 1983; UN/Unesco/UNEP, 1982), on some of the high islands in the Seychelles and Comoros, and in the ASEAN region, particularly Indonesia and Malaysia (Gomez, 1981) (see Table 2). Deforestation and logging, and agricultural malpractices such as slash-and-burn, have occurred throughout much of the region and mangroves, which act as sediment traps, have been reduced in most countries, particularly Indonesia (Gomez, 1981). The impact is often compounded by the input of fertilizers, pesticides and other pollutants. The total terrigenous load reaching the western Indian Ocean annually has been estimated at almost 500 000 000 cu m (Finn, 1983; UN/Unesco/UNEP, 1982). The responses of corals to sediment are very variable, many species being able to withstand low levels and others having behavioural or physiological responses to remove sediment (Grigg and Dollar, in press). Nevertheless, there are certainly many instances where damage is severe. Furthermore, siltation of this kind is often difficult to control, since the source of sediment may be far from the site of damage and come under the control of different agencies and government authorities.

**Industrial, domestic and agricultural pollution**

A review of sources of pollution in the Indian Ocean is given in Pathmarajah (1982) and UNEP (1982b). Problems in the South Asian Seas Region are reviewed in UNEP (in prep. a), in South-east Asia by Hungspreugs (1985), Kapauan (1985) and Morgan and Valencia (1983), and in the Red Sea and Gulf by IMO/ROPME/UNEP (1984).

Sewage pollution has been reported from a number of countries (Table 2) and is a potential problem in many more. For example, it has been estimated that 75% of all sewage in the KAP region enters the sea untreated (UNEP, 1985b). It causes eutrophication and ensuing accelerated algal growth which smothers corals; oxygen depletion and toxic contamination compound this (Johannes, 1975; Brown and Howard, 1985; Pastorok and Bilyard, 1985). Recovery of the reef may take place rapidly once the source of pollution is removed, and increasing efforts are now being made to place outfalls in water deeper than optimal for coral growth and in sites exposed to strong currents and unrestricted water circulation.

Thermal pollution, from power plants and industrial complexes, affects reproduction and may cause expulsion of zooxanthellae (bleaching), a temperature rise of 4°C generally causing damage. The long-term impact of heavy metals and other similar pollutants on coral reefs is still far from clear (Howard and Brown, 1984) but is of major concern in countries where mining is a major activity on the coast; Thailand, for example, is the top tin producing country in the world and mining activities have had a noticeable impact on reefs, mainly through sedimentation but possibly also through other forms of pollution (Chansang, 1985).

The impact of oil on coral reefs has been the subject of intensive research. Of particular concern are oil terminals, tanker traffic, refineries and offshore oil reserves adjacent to reefs, all of which are potential sources of pollution. The KAP region is probably most at risk as it has 57% of the known world oil reserves and 82% of the OPEC reserves (UNEP, 1985b). The closed nature of the Gulf makes it particularly susceptible. At present, most oil entering the sea in the Gulf is in the form of surface slicks, but increased pollution can be expected from tanker spills, tanker washings, pipeline breaks and effluent from the increasingly industrialized coast. The Nowruz spill in the Iranian oil field in 1983, during the Iran-Iraq war, resulted in the spilling of 2000-8000 barrels of oil a day which had a widespread impact on a variety of marine organisms (Reza, 1985; Burchard and McCain, 1984; Saad, 1984), particularly turtles, dugongs, echinoderms, crustaceans and corals. In the Red Sea, major sources of pollution are poorly maintained environmental standards in the Egyptian oil fields of the Gulf of Suez and deballasting by ships at sea, particularly in the southern Red Sea and Gulf of Aden (Gupta and Kureishy, 1981).

No major incidents involving oil have yet been reported from the other regions but East Asia is considered to be at risk and some oil pollution has been reported from Indonesia and the Philippines. With the rapid increase in oil activities, there is considered to be continuous low-level contamination from spills and vessel discharge, the Straits of Malacca and South China Sea being most vulnerable (Bilal, 1985). Similarly, the Eastern African Region is considered to be potentially at risk (IMO/UNEP, 1985).

In fact it appears that there is little long-term effect of oil on corals, although short-term sublethal effects may be felt (Knapp *et al.*, 1983) and reef fish may be affected (Gettleson, 1980). Single-event episodes, such as oil spills, rarely seem to have detrimental effects but chronic oil pollution may, particularly in the intertidal zone where the reef surface may be exposed to the air; there is no evidence that oil floating above the reef damages corals. Perhaps the greatest damage is from the clean-up operations which take place following spills, chemical detergents often being toxic. Extensive beach oiling seems to be a greater problem in the Red Sea than actual damage to the reefs.

**Coastal development**

Activities such as filling to provide sites for industry, housing, recreation, and airports, and dredging to create, deepen or improve harbours, ports and marinas have major impacts, through increased turbidity and altered water circulation, for example in Singapore, the Seychelles, the Lakshadweeps, the Jiddah and Yanbu areas in Saudi Arabia, Aqaba in Jordan. For example, sedimentation resulting from these activities is particularly prevalent in the KAP region where 20 major industrial centres are now being developed (UNEP, 1985b), largely as a result of the oil industry.

**Coral and sand mining**

Large quantities of coral and sand are mined for use as lime, and for road and building materials, particularly on islands where terrestrial sources of such materials are limited. This causes beach erosion and transportation of sand to other sites as a result of altered water circulation. Sedimentation and pollution from the introduction of toxic substances in the mining process also affect adjacent coral reefs (Dubois and Towle, 1985). Coral mining is a particularly serious issue in the Comoros, Maldives (where coral rock is used for roads), Sri Lanka and India (Palk Bay and Lakshadweep); many tens of thousands of tons may be removed annually. Similar problems have been recorded in the ASEAN countries, including Indonesia (Bali), Malaysia and the Philippines.

**Overexploitation**

Exploitation of reef species is increasing in countries where cash economies have been introduced relatively recently, in those with high population growth rates, and where tourism has expanded rapidly. In most cases, the concern is not with the extinction of species but with lowered reef productivity. A variety of fish and reef invertebrates (particularly spiny lobsters, and black and stony corals and a variety of molluscs, collected for the marine curio trade) have been heavily overexploited where they are important to local people, are in demand by tourists or make up a major export trade. The ornamental coral trade in the Philippines has led to significant localised reef damage; mother-of-pearl species have been overfished throughout much of the region and Giant Clams have been seriously depleted particularly in Indonesia and the Philippines. Ornamental shells are heavily exploited but the extent of impact on populations is not clear (Wells and Alcala, in press).

Fish catches have deteriorated markedly in many inshore reef areas and fishermen are now obliged to travel further afield to find new, undamaged reefs with worthwhile fish stocks and there is increasing concern about the aquarium fish industry in a number of Indian Ocean countries, including Indonesia, Sri Lanka, Thailand, the Philippines and Maldives (Wood, 1985 and see country sections).

**Deleterious fishing methods**

Although illegal in most countries in the Indian Ocean region, fishing using dynamite, fish poisons or intoxicants is widespread. These methods can be extremely damaging, destroying the reef, wasting fish and killing invertebrates. Dynamite fishing has been reported in 16 countries (Table 2) and takes place particularly in the South-east Asia, but also in Tanzania and some of the island nations. Muro-ami and kayakas fishing, which uses swimmers to drive the fish into the net by hitting the coral either with weights on long ropes or with bamboo poles, may also cause damage; such methods are widely used in Indonesia, Malaysia and the Philippines. Other damaging fishing methods include trawling close to reefs (Thailand), poling boats over the reefs, trampling on reef flats and misuse of fish traps. Spearfishing is a widespread and controversial fishing technique; in marine parks, it is generally considered unwise as large predators are removed. This causes an imbalance in the ecosystem, and fish populations tend to be more timid, a distinct disadvantage for snorkellers and underwater photographers.

**Intensive recreational use**

Although recreational activities are probably less widespread and therefore less damaging in the Indian Ocean than in the Caribbean, recreational activities, mainly associated with tourism, are increasingly being cited in the deterioration of reefs (see Table 2). At present this is mainly a problem in Thailand, the Philippines, Indonesia, Kenya and on some of the oceanic islands, particularly the Maldives and Seychelles. In the Red Sea and Gulf it is potentially a threat due to increased interest in recreational diving. Anchoring, boat groundings, trampling, littering, and exploitation of marine resources cause localized reef damage (Gomez, 1983). However, the main impact is probably not so much directly from these activities as from the indirect effect of tourist-generated pollution and coastal development. Tourist facilities are usually concentrated along narrow coastal strips and in semi-enclosed bays. Breakwaters and jetties are often constructed to protect beach fronts and this leads to the alteration of water circulation and erosion of beaches elsewhere.

## REEF MANAGEMENT

**Protected areas**

Reef management through a system of protected areas can help halt further degradation, facilitate the recovery of devastated areas, protect breeding stocks, improve recruitment in neighbouring areas and maintain the sustainable utilization of reef resources (Salm and Clark, 1984; Lien and Graham, 1985).

The economic benefits of marine parks in the Caribbean area are being increasingly recognised (van't Hof, 1985; Salm and Clark, 1984; Lien and Graham, 1985). Income to a park accrues through entrance fees, concessions from commercial diving and boat operators, permits for particular activities, direct management of commercial activities by park staff, and the sale of souvenirs and educational materials. Against this income is balanced the cost of staffing a park, the maintenance of facilities, the management of the environment where necessary, the provision of educational and recreational activities and in some cases the purchase of the site. Studies in the Caribbean have shown a benefit:cost ratio of 10:1 in some parks, particularly where SCUBA diving is an important activity (van't Hof, 1985). Substantial income is already being raised through some of the longer established marine parks in the Indian Ocean, for example in the Seychelles and Kenya (Salm, 1983).

An early discussion of marine parks in this region is given in IUCN (1976). Gomez *et al.* (1984) describe marine parks in the ASEAN region. Of the 41 countries included in this volume, 25 have a total of 87 protected areas which include coral reefs, but at least 17 of these have not been properly implemented (see Table 3). There are also 16 areas in which some form of fishing control operates. Several of the protected areas have been proposed for upgrading or improved management. Over 50 sites adjacent to terrestrial protected areas are recommended for inclusion or could be included, and over 200 other sites have been recommended for protection. The main problem is the lack of effective management for most parks, through lack of funding, trained personnel and expertise (White, 1984). However, some countries, such as Saudi Arabia, Oman, Sri Lanka, the Philippines, Malaysia and Thailand, are starting to develop comprehensive marine park programmes. Bahrain, Bangladesh, Chagos, Ethiopia, Kuwait, Maldives, Madagascar, North Yemen, Singapore, Somalia and South Yemen still have no coral reef protected areas but several of these countries have projects underway.

In South-east Asia, steps have been taken to establish a network of ASEAN Heritage Parks and Reserves under the auspices of ASEAN and UNEP, selected for their outstanding wilderness and other values. The only marine park so far included is Tarutao National Park in Thailand (ASEAN/UNEP, 1983).

The Corbett Action Plan for Protected Areas in the Indomalayan Realm puts particular emphasis on the need to pay special attention to the establishment and improved management of island coastal and marine protected areas (Thorsell, 1985) and at the 1985 Symposium on Endangered Marine Animals and Marine Parks, held in Cochin under the auspices of the Marine Biological Association of India, it was recommended that coral reefs should be given greater protection. The following areas are identified in the Corbett Action Plan as of particular importance:

- St Martin's Islands proposed Marine Park, Bangladesh
- Thamihla Kyun, South Moscos and Kadonly Kyun proposed marine reserves, Burma
- Parts of the Andaman, Nicobar and Lakshadweep archipelagoes
- Gulf of Mannar proposed Marine Park, India
- Coastal and marine habitats in Indonesia
- Honda Bay proposed Marine Park, Tubbataha Reef, San Miguel Island and Apo Reef, Philippines
- Waters adjacent to Wilpattu National Park, Sri Lanka
- Areas in Maldives and Chagos

The World Conservation Strategy emphasizes that any system of protected areas must aim to protect a representative selection of ecosystem types. This is still a problem as far as marine ecosystems are concerned, as there is no widely accepted classification. Problems in the classification of marine ecosystems are discussed by Ray (1975) and Salm (1984). Hayden *et al.* (1984) produced a preliminary classification based on attributes of the physical environment combined with faunal assemblage data.

Marine protected areas vary immensely in size, the area chosen often depending on practical rather than scientific considerations. The critical minimum core area for a coral reef protected area is considered by Salm (1984) to be the smallest area in which all coral species found in the overall area have a 100% chance of being found on all reefs of the same size. For example, in the Chagos Archipelago, core areas would correspond to at least 300 ha for each reef type (Salm, 1980). The remainder of the reserve (including reef-flats, land and intervening and surrounding waters) should function as a buffer and is zoned for different uses, permitting optimal use of the area by different interest groups with minimum conflict and maximum control. Reef flats and seagrass beds are often overlooked but are important in the recycling of nutrients in the reef ecosystem, and several fish have life cycles which involve two or more of these systems (Ogden and Gladfelter, 1983; SPC/SPEL/ESCAP/UNEP, 1985). The creation of protected areas around and including entire island systems, and the extension of boundaries of terrestrial protected areas to include marine habitats are effective means of achieving protection of a group of interrelated ecosystems. Large multiple use areas are therefore generally more practical than small reserves although sanctuaries or strict reserves may still be required for critical habitat areas, such as nutrient sources, areas of high biological diversity and nesting, or to protect breeding stocks of important fish (Salm and Clark, 1984).

The Man and the Biosphere programme (MAB), established in 1971 by Unesco, is of particular relevance in this context. One aim of the programme is the establishment of an international network of "Biosphere Reserves". These sites, selected to provide representative examples of the world's major ecosystems, encompass multiple zones including one or more highly protected core areas (to protect natural ecosystems and genetic diversity), traditional use areas (to study and document traditional use patterns), experimental areas (for manipulative research on resource utilisation) and rehabilitation areas (to study techniques for the restoration of degraded ecosystems). They must also offer possibilities for sharing personnel and educational research and training facilities and have the potential for involving local communities in research and educational programmes.

The 1984 Action Plan for Biosphere Reserves emphasizes the need to improve representation of coastal and aquatic ecosystems. Of the 252 listed Biosphere sites, less than a dozen include or are adjacent to reefs, and of these, only three (Kiunga and Malindi-Watamu in Kenya; Puerta Galera in the Philippines) lie within the region covered by this volume. Biosphere Reserves are particularly appropriate for the coastal zone owing to their emphasis on linkages between conservation and development and because of the difficulty of including complete marine and coastal ecosystems within traditional forms of protected areas. In the Caribbean, a multi-national conservation area is now being developed under this programme. The potential for a multi-national reserve covering the waters and reefs of the Sulu Sea within Philippine, Malaysian and Indonesian boundaries has been discussed and could be developed along similar lines. It has also be suggested that the Indian Ocean Sanctuary concept, designed primarily for cetaceans, could be extended to other species and habitats (IUCN/UNEP, 1984).

While biosphere reserves are aimed at protecting representative samples of ecosystems, the World Heritage Site system has been designed to conserve unique and outstanding examples of the world's natural heritage. These may be nominated by parties to the World Heritage Convention (Convention concerning the Protection of the World Cultural and Natural Heritage), concluded at Paris, 23 November 1972. Of the 62 listed natural sites, the following include or are adjacent to reefs: Aldabra, Great Barrier Reef (Australia), Sierra Nevada de Santa Marta (Colombia) and the Gal#pagos. There is clearly scope for listing other reefs on this convention.

**Coastal zone management planning**

Given that a major problem in the Indian Ocean region is the enforcement of regulations concerning protected areas and exploitation, coastal zone management planning is particularly important. Reef management has increasingly to be considered in the context of the entire coastal zone, and even catchment area, and is particularly important where siltation, caused by upstream sources, is a problem (Finn, 1982 and 1983). The technology to avoid much human-induced damage to coral reefs is now available. For example, sewage outfalls can be placed below the level of coral growth, thermal effluent can be discharged in deep water, there are new methods for dispersing oil and alternative materials to coral are available for construction. This technology is often not applied owing to lack of technical expertise, funding or co-ordination between the relevant government authorities, but many countries are now moving in this direction.

This relatively new field is discussed by Sorensen *et al.* (1984) and Snedaker and Getter (1985) who provide guidelines for the creation of national coastal resources management programmes; actions by international aid organizations; land use and coastal planning; and environmental impact assessment, many of which are specific to coral reefs. The International Affairs Office of the U.S. National Parks Service, in co-operation with the U.S. Agency for International Development and other organizations, has set up the C.A.M.P. (Coastal Area Management and Planning) Network to provide information and training opportunities.

An ASEAN/USAID Coastal Resource Management Project was initiated in 1985 and is being executed through ICLARM (see below). It aims to assist the ASEAN nations to develop their coastal resources on a sustainable basis and has two components: the development of site-specific coastal resource management plans and the dissemination of information, through for example handbooks on coral reefs (White, in press), and the development of training activities. Of the six sites chosen for coastal resource management plan development, two have reefs: Ban Don and Phangnga Bay in Thailand and the offshore islands of Singapore (Anon., 1986c; Chua, 1986; Dubois, 1986). Other countries such as Sri Lanka and Oman are developing national coastal management programmes.

The Unesco Coral Reef Management Handbook (Kenchington and Hudson, 1984) aims to provide political, administrative and technical decision-makers who have responsibility for coral reefs with the means to ensure that relevant issues are properly considered in the course of their work. UNEP is currently preparing a set of Coral Reef Management Guidelines in collaboration with the Australian Great Barrier Reef Marine Park Authority.

**Reef fisheries management**

The World Conservation Strategy recommends that the maintenance of coral reef fisheries at sustainable levels be considered a global priority. Fisheries management in the region is monitored by ICLARM (International Center for Living Aquatic Resources Management), which promotes sustainable utilisation of aquatic resources and has a number of reef-related projects (Pauly, 1986) and SEAFDEC (Southeast Asian Fisheries Development Center). Most countries in the region covered by this volume have national legislation to regulate fisheries, including lobster and sometimes corals (Table 4); a review of relevant legislation in the Eastern African Region is given in FAO/UNEP (1983). This however, has generally been enacted on an *ad hoc* basis for particular species. In the Caribbean, a Fisheries Act has been developed under the auspices of the Organization of Eastern Caribbean States (OECS) and FAO which provides for the preparation of fisheries management and development plans, appointment of national fisheries advisory committees, regional co-operation, establishment of marine reserves and conservation programmes and prohibition of certain methods (Goodwin, 1985). A similar regional approach to fisheries legislation might be appropriate in some parts of the Indian Ocean. Recommendations of improved management of the aquarium fish trade are given in Wood (1985).

Despite overfishing of many traditional resources, landings could probably be improved through stock enhancement, such as use of underexploited non-reef species, artificial reefs and other fish aggregating devices. Most work on artificial reefs has been carried out in the Caribbean, but artificial reef programmes are under way in Kuwait and the Philippines. Non-destructive aquaculture methods can be carried out on the reef flats and the market for underexploited protein sources on the reef, such as sea cucumbers, urchins and molluscs, needs to be tapped (Gomez, 1980). There is increasing mariculture potential for a heavily exploited species. A regional progamme for Giant Clam farming is under way under the auspices of ICLARM and includes the Philippines (Lucas and Munro, 1985). Research on mother-of-pearl farming is being carried out in Sudan. The ornamental coral and shell trades need better control, both nationally and internationally (Wells and Alcala, in press). The shell trade provides an important source of income and many molluscs can probably support fairly intense exploitation, but the trade needs improved management to prevent damage to the reef environment and local overexploitation of the more popular species. The Indian Ocean Alliance recommended that the problem of ornamental shell collecting should be considered at the national level and that protected areas for breeding populations should be established (IUCN/UNEP, 1985b); the Seychelles has the only known protected areas for molluscs but these have never been monitored to determine their success.

The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), concluded in Washington D.C., 1973, provides a mechanism for controlling international trade in threatened species. However, although many reef species are involved in international trade, few fit the strict criteria required for listing on the Appendices. All turtles (Cheloniidae and Dermochelydae) and the Dugong *Dugong dugong* (except Australian populations) are listed in Appendix I which prohibits international trade between parties. Black coral (Antipatharia), the Giant Clams Tridacnidae and a number of stony coral genera are listed in Appendix II, which means that an export permit is required from the country of origin.

**Research, training and education**

Research into the coastal zone has increased dramatically in recent years, particularly in relation to the conflict between economic development and natural resource conservation, although, compared with the Caribbean and Australia, reef-related research in the Indian Ocean is still low-scale. UNEP/PNUE (1978), UNEP/FAO (1985) and Morgan and Valencia (1983) provide information on marine research and environmental centres in the region, many of which are undertaking reef research and management programmes. A world list of coral reef research institutes is currently being prepared by Eldredge and Potter (in prep.); information on marine research institutes and scientists is also available in Unesco/FAO (1983).

The Division of Marine Sciences of Unesco has played a major role in stimulating such research and training specialists and technicians in marine sciences through the Major Inter-regional Project on Research and Training leading to Integrated Management of Coastal Systems (COMAR). Pilot projects are being drawn up to give each region the practical experience and background for decision-making in the field of coastal zone management (Unesco, 1986). These include projects on productivity and interactions between coral reefs, seagrasses and mangroves; and traditional knowledge and management of coastal and marine ecosystems. Traditional knowledge and management of reefs is relatively unknown in Asia compared with the Pacific but considerable work has been carried out in Indonesia (Ruddle and Johannes, 1985). Further work is required to assess application of such knowledge. In Asia (and the Pacific) COMAR activities have focused on coral reefs, mangroves and traditional knowledge and the development of a network of coral reef institutions (Unesco, 1982). A Unesco/UNEP workshop on Coral Reef survey methods was held in Phuket, Thailand, in 1982 (Unesco, 1984) and a taxonomy workshop in 1984 for the South-east Asian Region (Unesco, n.d.). In 1985, a COMAR project on assessing coral reef damage caused by human activities was held in Indonesia (Brown, in press). International seminars are also held in the U.S.A. for administrators, managers and professional personnel involved in coastal and marine protected areas policy, planning, design, management and operations (Anon., 1986a).

Research priorities for the East Asian Region include studying the effects of sedimentation and blast fishing on reefs, regeneration rates, comparing productivity of stressed and unstressed reefs and determining of sustainable yield (Gomez, 1980). Work on some of these issues is currently under way, including a survey of the state of coral resources and a study of the effects of pollutants and other destructive factors, which are being funded as part of the UNEP Regional Seas Programme and the East Asian Seas Trust Fund and being implemented by the Philippines. Future research and management requirements in the Red Sea are discussed in Saad (1984).

Monitoring changes on reefs is a high priority (Brown and Howard, 1985). Simple, low-cost techniques for assessment have been designed for the Pacific (Dahl, 1981) and the Eastern Caribbean (Goodwin *et al.*, 1986) and are appropriate for much of the area considered in this volume. Remote sensing of coral reefs, although costly, is becoming an increasingly useful technique, and a training course in Australia on the subject has recently been run under the auspices of the Unesco COMAR project.

Education programmes in schools and villages are also extremely important to help local people to understand the importance of reef resources and lead to improved enforcement of planning controls and regulations. Particularly successful efforts are under way in the Philippines. Foreign visitors and tourists also need to understand the reef ecosystem, and marine parks are increasingly contributing to this through their provision of interpretative centres, underwater trails and guidebooks.

**International and regional efforts**

Multinational collaboration and regional strategies are particularly important in the conservation and management of marine resources which are so often shared by several countries. Kenchington and Hudson (1984) summarize the international agencies and organizations which carry out activities relating to reef management. The following is a guide to those of particular relevance to the area covered by this volume.

*Indian Ocean Alliance*

Formed in 1980 by governments of the Indian Ocean coastal states to work together for conservation in a number of ways including the rational use of natural resources and the initiation of conservation related research.

*ASEAN Association of South East Asian Nations*

With six member countries (Brunei, Indonesia, Malaysia, the Philippines, Singapore and Thailand), this is a political and economic body founded in 1967 for technical collaboration for the attainment of peace, progress and prosperity. It has adopted a co-operative programme to ensure that environmental considerations are incorporated into all aspects of economic development.

*UNEP Regional Seas Programme*

The Regional Seas Programme was initiated by UNEP in 1974. Since then the Governing Council of UNEP has repeatedly endorsed a regional approach to the control of marine pollution and the management of marine and coastal resources and has requested the development of regional action plans.

The Regional Seas Programme at present includes ten regions and has over 120 coastal States participating in it. It is conceived as an action-orientated programme having concern not only for the consequences but also for the causes of environmental degradation and encompassing a comprehensive approach to combating environmental problems through the management of marine and coastal areas. Each regional action plan is formulated according to the needs of the region as perceived by the Governments concerned. It is designed to link assessment of the quality of the marine environment and the causes of its deterioration with activities for the management and development of the marine and coastal environment. The action plans promote the parallel development of regional legal agreements and of action-orientated programme activities.

An important UNEP contribution to the concept of promoting regional cooperation in assessing and combating marine pollution together with resource conservation and management in oceans and coastal areas has been the preparation and publication of a series of regional directories and bibliographies.

UNEP's recognition of the environmental importance of coral reefs, as well as the tremendous pressures on and global exploitation of these fragile ecosystems, has been demonstrated in the inclusion and encouragement of various measures to protect reefs in the regional action plans. The publication of the Pacific Coral Reef Researchers in UNEP's Regional Seas Directories and Bibliographies (UNEP/PSA/SPREP/UG, 1984) is also an indication of this concern. In order to give coral reefs and associated problems a deservedly much greater exposure it was decided to publish the three volumes of directories that would cover the coral reefs globally.

This volume covers five regions defined by the UNEP Regional Seas Programme. An overview of the activities of the Programme in the region is given in UNEP (1985b). The following is a brief review of these regions:

*Kuwait Action Plan Region* - an Action Plan for the Protection and Development of the Marine Environment and the Coastal Areas of Bahrain, Iran, Iraq, Kuwait, Oman, Qatar, Saudi Arabia and the United Arab Emirates was adopted in Kuwait, April 1978, in addition to the Kuwait Regional Convention for Co-operation on the Protection of the Marine Environment from Pollution and the Protocol concerning Regional Co-operation in combating Pollution by Oil and Other Harmful Substances in cases of Emergency (UNEP, 1983b). The secretariat is provided by the Regional Organisation for the Protection of the Marine Environment (ROPME) in Kuwait. A number of projects have been carried out, largely directed towards controlling pollution (IMO/ROPME/UNEP, 1984; UNEP, 1985a). There are two regional oil spill response schemes: the Marine Emergency Mutual Aid Centre (MEMAC) and the Gulf Area Oil Companies Mutual Aid Organisation (GAOCMAO). ROPME has supported a series of ecological studies with IUCN (IUCN/UNEP, 1985f).

*Red Sea and Gulf of Aden Environmental Programme (PERGSA)* - established in 1976 and revised in 1982 with heavy emphasis on conservation of the environment in relation to expanding economic and social development. It is based in Jiddah at ALECSO (Arab League Educational, Cultural and Scientific Organisation). The Action Plan for the Conservation of the Marine Environment and Coastal Areas in the Red Sea and Gulf of Aden was adopted in Jiddah, 1982, together with the Regional Convention for the Conservation of the Red Sea and Gulf of Aden Environment and the Protocol concerning Regional Co-operation in Combating Pollution by Oil and Other Harmful Substances in Cases of Emergency (UNEP, 1986). A number of seminars, training courses and workshops have been held, such as the Symposium on the Red Sea, Gulf of Aden and coastal North-west Indian Ocean held in Sudan in 1983 and the Symposium on the coral reef environment of the Red Sea held in Jiddah in 1984.

*Eastern African Region* - An Action Plan for the Protection, Management and Development of the Marine and Coastal Environment of the Eastern African Region was adopted in Nairobi in 1985, with the Convention for the Protection, Management and Development of the Marine and Coastal Environment of the Eastern African region, the Protocol concerning Protected Areas and Wild Fauna and Flora in the Eastern African Region and the Protocol concerning Co-operation in Combating Marine Pollution in Cases of Emergency in the Eastern African Region. Activities leading up to the development of the plan are described in UNEP (1984b) and included the development of a pilot study of coastal zone management and protection in Mauritius with the involvement of the South Carolina Sea Grant Consortium (Dobbin *et al.*, 1983; Sparks, 1983).

*South Asian Seas Region* - established in 1983 and has yet to produce an Action Plan but is working towards this. Country reports have been published to provide the necessary baseline data (IUCN/UNEP, 1985c). These are being summarized as an overview of the marine and environmental problems of the Region. A draft of this and a draft Action Plan was presented to a meeting of experts in Bangkok in December 1986 (UNEP, in prep. a).

*East Asian Region* - covering the ASEAN area, this region is not developing a Convention at present (Snidvongs, 1985; UNEP, 1985b). The Action Plan for the Protection and Development of the Marine Environment and Coastal Areas of the East Asian Region was adopted in Manila, April 1981 and its implementation was subsequently determined in Bangkok, December 1981 (UNEP, 1983a). Many of its areas of action are a continuation of work carried out under the ASEAN Environment Programme (ASEP), which has been underway since 1978 (Snidvongs, 1985; Gomez, 1980). The programme includes a project on the assessment of pollution and degradative factors on coral reef ecosystems and related fisheries; this is co-ordinated by the Natural Resources Management Council in the Philippines and is jointly involved with the Unesco COMAR projects and training workshops, there being a strong emphasis on training. A review of the status of the marine and coastal environment of the East Asian Region is currently in progress (UNEP, in prep. b).

### *IUCN and WWF*

IUCN/WWF activities in the region include the development of marine parks and the general support of the national park services in several countries, including Thailand, Indonesia, Malaysia and India, through assistance provided by the IUCN Commission on National Parks and Protected Areas (CNPPA). The

Conservation for Development Centre of IUCN is contributing to the development of National Conservation Strategies in Madagascar, Vietnam, Pakistan and Bangladesh, and may assist with strategies for Saudi Arabia, Oman, Kenya, Maldives, and Seychelles. These will take reef ecosystems, where relevant, into account. IUCN has also contributed to the development of coastal zone management plans in Saudi Arabia and the Sultanate of Oman.

*Unesco*

Unesco's main involvement in the region, as far as coral reefs are concerned, is in terms of its Man and the Biosphere Programme and research and training activities, both of which are described above.

**International conventions**

Most international wildlife conventions make little reference to coral reefs. CITES and the World Heritage Convention were mentioned above. Other conventions of relevance are described in IUCN/UNEP (1985f) and FAO/UNEP (1983). The following conventions also have, or could have, some bearing on reef management and conservation:

The Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, 1972 and the International Convention for the Prevention of Marine Pollution from Ships (MARPOL 73/78) have been drawn up by the International Maritime Organization to prevent marine pollution from ships which may often have a direct impact on reefs. They are discussed by Kenchington and Hudson (1984).

The Convention on Wetlands of International Importance especially as Waterfowl Habitat, concluded at Ramsar, Iran, 2 February 1971, lists wetlands of international importance primarily to waterfowl, but sites may be selected on a variety of criteria. Wetlands are defined as areas of marsh, fen, peatland or water, fresh and marine, the depth of which at low tide does not exceed six metres; shallow coral reefs are therefore included. At present the only Ramsar site which includes reefs is the St Lucia System in South Africa. It is generally felt that, in its present form, the Convention is not appropriate for reefs since a) the emphasis is strongly on bird habitat, b) reefs generally extend to depths greater than 6 m, and c) reefs generally come under different national legislation from other wetland habitats, which would complicate the implementation of the Convention within a country (Anon., 1986b; Wells, 1984). However, efforts are currently under way to revise the convention to make it an important force for the protection of coastal wetlands essential for supporting fisheries.

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## TABLE 1: DAMAGE TO REEFS DUE TO NATURAL EVENTS

Information has not been obtained for Bangladesh, Brunei, Burma, Djibouti, Iran, Madagascar, Mozambique, North Yemen, Pakistan, Qatar, Singapore, Somalia, South Yemen, Tanzania, United Arab Emirates and Vietnam.

The coral predators which have been recorded as having an impact on the reefs are the Crown-of-Thorns Starfish *Acanthaster planci*, the sea urchins *Echinometra mathaei, Diadema setosum, Heterocentrotus mammillatus, Tripneustes gratilla*, and the molluscan gastropod *Drupella rugosa*.

* = damage not reported

| | Climate, tides and tectonic events | Coral predators | Disease |
|---|---|---|---|
| Australia - Western | storms, cyclones (Kimberley coast, Houtman Abrolhos, Lowendal and Montebello Is), earthquake (1876, Cocos Keeling) | *A. planci* (1970s, Lowendal Is) | |
| Bahrain | | *E. mathaei* (1983) | |
| Chagos | low tides, earth tremors | *A. planci* (1970s, Speakers Bank) | |
| Comoros | coral bleaching (1983, Mayotte) | *A. planci* (1970s, Mayotte) | |
| Egypt | | *H. mammillatus, D. setosum, E. mathaei* (1970s, Hurghada area) | |
| Ethiopia | storms (Dahlak Archipelago) | | |
| India | cyclone (1976, Gulf of Kutch, Lakshadweep), monsoon rain (Palk Bay) | *A. planci* (1980s, Andamans*; 1970s, Lakshadweep, Nicobar) | |
| Indonesia | Volcano (1815, Sumbawa) coral bleaching (1983, K. Seribu, Karimunjawa) | *A. planci* (1980s, Irian Jaya, K. Seribu*) | |
| Israel | low tides (1970, 1983) | | |
| Jordan | low tides (1983, 1985) | *D. setosum, E. diadema, T. gratilla* (1970s) | |
| Kenya | | *E. mathaei** (1980s) *A. planci* (1970s) | |
| Kuwait | cold temperatures, low tides | *E. mathaei* (1980s) | |
| Malaysia | low tides (east coast, Peninsular Malaysia) | *A. planci* (1970s, 1980s) | |
| Maldives | | *A. planci* (1970s, Male) | |
| Mauritius | cyclone (1960 and others) | *T. gratilla, E. mathaei* (1970s) *A. planci* (1970s-80s) | |
| Philippines | typhoons (1984 Mactan, Moalboal, Sumilon, Carbin Reef?) | *D. rugosa* (1980s, Mactan), *A. planci* (Apo I., Cagayen Is, Alcoy, Bantayan I., Bolinao, Panglao I.) | |
| Qatar | cold temperatures, "Shamals" | | |

Table 1 (Contd)

| | Climate, tides and tectonic events | Coral predators | Disease |
|---|---|---|---|
| Réunion | coral bleaching (1983) | | |
| Saudi Arabia | | *A. planci** | White and black band (1984, Jeddah) |
| Seychelles | | *A. planci* (1970s, Praslin, Mahé*) | Black band (1974/75, Mahé) |
| South Africa | flooding | | |
| Sri Lanka | monsoon storms | *A. planci* (1970s) | |
| Sudan | | *A. planci* (1970s*) | |
| Sultanate of Oman | cold temperatures, rock slides (Musandam) | *A. planci* (1980s) | |
| Thailand | low tides (Phuket, 1980) | *A. planci* (1970s, Gulf*, 1980s, Andaman Sea) | |
| United Arab Emirates | cold temperatures | | |

## TABLE 2: KNOWN THREATS TO REEFS

| | Erosion/land clearance | Construction/ dredging | Pollution | Overcollection | Recreational use | Fishing activities |
|---|---|---|---|---|---|---|
| Australia - Western | | dredging | oil* | trochus, shells, lobster, fish, coral | tourism,* anchor damage | dynamiting, spearfishing |
| Bahrain | | causeway construction, dredging, filling, reclamation | oil,* chemicals* | fish | anchor damage | |
| Bangladesh | | | sewage* industrial* | shells, corals | tourism | dynamiting |
| Burma | | | | | | |
| Chagos | | dredging | shipping* | | | |
| Comoros | deforestation | coral and sand mining | | lobsters, shells | diving* | dynamiting, poison |
| Djibouti | | unspecified | shipping* | fish, corals, shells | anchor damage, boat traffic | spearfishing, |
| Egypt | | | oil, litter | fish, lobsters | tourism, anchor damage, diving* | spearfishing, dynamiting |
| Ethiopia | | | | corals, shells | littering | |
| India | deforestation, agriculture | coral and sand mining | oil*, industry,* sewage | trochus | tourism* | dynamiting |
| Indonesia | mangroves, agriculture | coral mining, hotels, harbours | industrial, sewage, oil* | fish, shells, mother-of-pearl, Giant Clams | tourism | dynamiting, trampling, anchor damage, spearfishing, muro-ami, fish traps |
| Iran | | | oil,* refuse | | littering | |
| Israel | | hotels, harbours | oil, phosphate | | tourism* | |

Table 2 (Contd)

| | Erosion/land clearance | Construction/ dredging | Pollution | Overcollection | Recreational use | Fishing activities |
|---|---|---|---|---|---|---|
| Jordan | | filling | oil,* shipping,* phosphate, industrial* | | | anchor damage, dynamiting |
| Kenya | agriculture | | industrial,* domestic,* oil* | shells, corals | trampling | miscellaneous |
| Kuwait | | industrial, urban | oil* | | littering, anchor damage | |
| Madagascar | deforestation* | | | fish, pearl oysters | | miscellaneous |
| Malaysia | logging, agriculture | coral and sand mining | sewage, oil,* litter | fish, shells | tourism | dynamiting, trawling, spearfishing, trampling |
| Maldives | | hotels, airport infilling, dredging coral mining | industrial,* shipping, sewage | shells, fish, corals | anchor damage, divers* | spearfishing, dynamiting |
| Mauritius | deforestation | tidal power,* hotels, coral and sand mining | pesticides,* sewage | coral, shells, fish | anchor damage, tourism | anchor damage, dynamiting, seine nets |
| Mozambique | agriculture* | | pesticides,* fertilizers,* industrial* | | tourism* | spearfishing, dynamiting |
| North Yemen | | | | | | |
| Philippines | logging, agriculture, mangrove destruction* | coral and sand mining | copper mining, oil,* shipping, litter | coral, shells, Giant Clams, fish | boat groundings, diving,* tourism, anchor damage | dynamiting, muro-ami, kayakas, anchor damage, poisons, spearfishing |
| Qatar | | | sewage,* oil* | | | |
| Réunion | deforestation | | sewage,* agricultural, chemical | corals, shells, lobsters, *Turbo* | | trampling, spearfishing, dynamiting |

Table 2 (Contd)

| | Erosion/land clearance | Construction/ dredging | Pollution | Overcollection | Recreational use | Fishing activities |
|---|---|---|---|---|---|---|
| Saudi Arabia | | industrial, urban, filling, dredging, roads, harbours | sewage, oil, chemical, refuse, shipping, heavy metals, | fish, coral, molluscs | trampling, littering | spearfishing |
| Seychelles | agriculture* | filling, airport, dredging, coral mining | sewage* | lobsters, corals, shells | littering | |
| Singapore | | filling | oil,* shipping | shells, corals | anchor damage | |
| Somalia | overgrazing* | sand mining, dredging | oil,* sewage* | | | |
| South Africa | | harbour* | | | diving,* boats* | |
| South Yemen | | | oil* | | | |
| Sri Lanka | | coral mining | coconut soaking | fish, corals, shells | tourism | anchor damage, dynamiting, spearfishing |
| Sudan | | | industrial, sewage, oil,* shipping | corals, shells | littering, anchor damage, diving | spearfishing |
| Sultanate of Oman | | marinas* | oil* | corals,* shells, lobsters | littering,* diving* | traps, fishing nets,* spearfishing |
| Tanzania | deforestation* | | sewage | corals, shells | | dynamiting, trampling |
| Thailand | agriculture | harbour, jetties, sand mining | sewage, heavy metals, tin mining | fish, lobsters, shells | anchor damage | dynamiting, trawling |
| United Arab Emirates | | | | | | |

* = potential threat.

## TABLE 3: EXISTING AND PROPOSED OR RECOMMENDED PROTECTED AREAS ADJACENT TO OR INCLUDING REEFS

* = party to World Heritage Convention
\+ = category unassigned
() = marine habitats not included within protected area
F = some controls over fishing/fishing reserve
I. = Island
Is = Islands

For explanation of categories, see end of table; a symbol in the second column when there is also one in the first indicates that there is a proposal to upgrade the protected area or create a marine extension.

| | Established | Proposed/ Recommended |
|---|---|---|
| AUSTRALIA, WESTERN* | | |
| Ashmore Reef National Nature Reserve | IV | |
| Ningaloo Marine Park | + | |
| Marmion Marine Park | II | |
| Muiron Is Nature Reserve | (IV) | + |
| Christmas I. National Park | (II) | + |
| Barrow I. Nature Reserve | (IV) | + |
| Houtman Abrolhos Is Reserves | (IV) | + |
| Dampier Archipelago Reserves | (IV) | + |
| Kimberley Coast Reserves | (IV) | + |
| Lowendal Is Nature Reserve | (IV) | |
| Monte Bello Is | | + |
| Rowley Shoals | | + |
| Shark Bay | | + |
| BAHRAIN | | |
| Sitrah, Nabi, Saleh, Al Muharraq and Zida Is | | + |
| BANGLADESH* | | |
| St Martin's Island | | + |
| BURMA | | |
| Moscos Islands Wildlife Sanctuary | (+) | + |
| Thamihla Kyun Wildlife Sanctuary | (+) | + |
| Lampi Marine National Park | | + |
| Kadonly Kyun Wildlife Sanctuary | | + |
| CHAGOS | | |
| Great Chagos Bank | | + |
| COMOROS | | |
| Nioumachoua Is, Mohéli | | + |
| Bangoi Kouni/Ivoini, Grand Comore | | + |
| Chindini/Malé, Grand Comore | | + |
| Chiroroni, Anjouan | | + |
| Mayotte Barrier Reef | F | + |
| DJIBOUTI | | |
| (? = reserves declared for five years in 1972; current status not known) | | |
| Parc Territorial de Musha | + | |
| Réserve Intégrale de Maskali Sud | + | |
| Réserve de Tadjourah | +? | |
| Réserve d'Obock | +? | |
| Réserve d'Arta | +? | |
| EGYPT* | | |
| Ras Muhammad Marine National Park (inc. Tiran and Sinafir Natural Reserves) | II | |

Table 3 (Contd)

| | Established | Proposed/ Recommended |
|---|---|---|
| EGYPT (Contd) | | |
| Gebel Elba Conservation Area | + | |
| Hurghada | | + |
| Shadwan | | + |
| Southern Egypt | | + |
| Hurghada Marine Biological Station | | + |
| Giftun Is | | + |
| ETHIOPIA* | | |
| Dahlak Is | | + |
| INDIA* | | |
| Gulf of Kutch Marine Sanctuary and Marine National Park | II/IV | |
| Wandur Marine National Park | + | |
| Lakshadweep | | + |
| Pitti I. | (+) | |
| Gulf of Mannar Marine National Park | | + |
| Nicobar Is | | + |
| Malvan coast | | + |
| Anjadiv I. | | + |
| Palk Bay | | + |
| INDONESIA | | |
| (For recommended extensions to terrestrial protected areas, see text) | | |
| (MUMA = Multiple Use Management Area) | | |
| (MMR = Managed Marine Reserve) | | |
| INDONESIA - SUMATRA | | |
| Pulau Weh Marine Park | II | |
| Kayu Ara Strict Marine Reserve | | + |
| Kebatu Strict Marine Reserve | | + |
| Kepulauan Anambas Selatan MUMA | | + |
| Kepulauan Banyak-Bangkaru MUMA | | + |
| Kepulauan Riau Selatan-Lingga Utara MUMA | | + |
| Mandariki Strict Marine Reserve | | + |
| Muara Siberut Marine Nature Reserve | | + |
| Perairan Kepulauan Batu MUMA | | + |
| Pulau Bangka Timur MUMA | | + |
| Pulau Lengkuas-Pulau Kepayang MMR | | + |
| Pulau Penyu Strict Marine Reserve | | + |
| Pulau Segamat Strict Marine Reserve | | + |
| Tambelan-Uwi MUMA | | + |
| Perairan Manggar Tenggara-Pulau Rotan MUMA | | + |
| Teluk Bolok-Kepulauan Lima MUMA | | + |
| INDONESIA - JAVA | | |
| Penanjung Pangandaran Nature Reserve | I | |
| Baluran "National Park" | | + |
| Ujung Kulon "National Park" | | + |
| Kepulauan Seribu Strict Nature Reserve and "Marine Park" | I | + |
| Karimunjawa Wildlife Reserve | | + |
| Perairan Kangean Utara MUMA | | + |
| Pulau Sangiang Protected Seascape | | + |
| INDONESIA - NUSA TENGGARA | | |
| Bali Barat "National Park" | | + |
| Komodo Biosphere Reserve and "National Park" | IX | + |
| Pulau Moyo Wildlife Reserve | (IV) | + |
| Bakau Landu MMR | | + |
| Batugengdang Wildlife Reserve | | + |
| Gili Air-Pulau Pemenang Wildlife Reserve | | + |

Table 3 (Contd)

| | Established | Proposed/ Recommended |
|---|---|---|
| INDONESIA - NUSA TENGGARA (Contd) | | |
| Kepulauan Tujuhbelas Wildlife Reserve | | + |
| Nusa Penida Marine Park | | + |
| Pulau Rakit Marine Recreation Park | | + |
| Pulau Satonda Marine Recreation Park | | + |
| Teluk Kupang-Pulau Kera Marine Recreation Park | | + |
| Uluwatu Strict Marine Reserve | | + |
| INDONESIA - KALIMANTAN | | |
| Pulau Sangalaki Marine Park | IV | |
| Pulau Semama Wildlife Reserve | IV | |
| Karimata Strict Nature Reserve | | + |
| Kepulauan Laut Kecil MUMA | | + |
| Kepulauan Balangan-Pulau Uwi MUMA | | + |
| Pulau Maratua-Karang Muaras Strict Nature Reserve | | + |
| INDONESIA - MALUKU | | |
| Pulau Angwarmase Strict Nature Reserve | I | |
| Pulau Banda Strict Nature Reserve and Marine Park | II/IV | |
| Pulau Kasa Wildlife Reserve and Marine Park | II/IV | |
| Pulau Pombo Strict Nature Reserve and Marine Park | II/IV | |
| Aru Tenggara Strict Nature Reserve and Marine Park | | + |
| Kepulauan Kai Barat-Tayandu Marine Multiple-Use Reserve | | + |
| Kepulauan Sermata Barat MUMA | | + |
| Pulau Babi Marine Park | | + |
| Pulau Penyu-Pulau Lucipara Strict Nature Reserve | | + |
| Pulau Suanggi Strict Marine Reserve | | + |
| Teluk Ambon Marine Multiple-Use Reserve | | + |
| Yamdena Strict Marine Reserve | | + |
| INDONESIA - SULAWESI | | |
| Tangkoko-Dua Saudara Strict Nature Reserve | I | |
| Tanjung Amolenggo Wildlife Reserve | IV | |
| Tanjung Batikolo Wildlife Reserve | IV | |
| Tanjung Api Strict Nature Reserve | (I) | + |
| Arakan Wildlife Reserve | | + |
| Karompa Tjadi Strict Marine Reserve | | + |
| Kepulauan Bunaken Marine Recreation Park | | + |
| Kepulauan Kalukalukuang MUMA | | + |
| Kepulauan Peleng-Banggai Strict Nature Reserve | | + |
| Kepulauan Sangihe-Talaud Wildlife Reserve | | + |
| Kepulauan Sembilan MMR | | + |
| Kepulauan Tengah-Kepulauan Sabalana MUMA | | + |
| Kepulauan Togian Marine Multiple-Use Reserve | | + |
| Pulau Kakabia (Kawi-Kawi) Strict Nature Reserve | | + |
| Pulau Maromaho Strict Marine Reserve | | + |
| Pulau Pasoso Wildlife Reserve | | + |
| Pulau Pulau Spermonde-Pulau Samalona Marine National Park | | + |
| Pulau Pulau Tiga Wildlife Reserve | | + |
| Sangi Sangiang Strict Marine Reserve | | + |
| Selat Muna Wildlife Reserve | | + |
| Selat Wowoni Strict Nature Reserve | | + |
| Taka Bone Rate Wildlife Reserve | | + |
| Teluk Lasolo-Teluk Dalam Wildlife Reserve | | + |
| Tukang Besi Wildlife Reserve | | + |
| INDONESIA - IRIAN JAYA | | |
| Pulau Sabuda-Pulau Tataruga Wildlife Reserve | IV | |
| Jef Jus Strict Marine Reserve | | + |
| Kepulauan Ayu-Asia Wildlife Reserve | | + |
| Pulau Mapia Wildlife Reserve | | + |

Table 3 (Contd)

| | Established | Proposed/ Recommended |
|---|---|---|
| INDONESIA - IRIAN JAYA (Contd) | | |
| Pulau Sayang MMR | | + |
| Raja Ampat Wildlife Reserve | | + |
| Teluk Cenderawasih-Kepulauan Auri Wildlife Reserve | | + |
| Teluk Lelintah Wildlife Reserve | | + |
| IRAN* | | |
| Shotur I. Reserve | I | |
| Chah Bahar | | + |
| Hormuz I. | | + |
| Pozm Bay | | + |
| ISRAEL | | |
| Eilat Coral Reserve | IV | |
| JORDAN* | | |
| Marine Nature Reserve | + | |
| Marine Park and Environmental Management Zone | | + |
| KENYA | | |
| Kisite Marine National Park | II | |
| Mpunguti Marine National Reserve | IV | |
| Kiunga Marine National Reserve and Biosphere Reserve | VI/IX | |
| Malindi and Watamu Marine National Parks Reserves and Biosphere Reserve | II/IX | |
| Diani Marine National Park Complex | | II |
| Ras Tenewi Coastal Zone National Park | | II |
| KUWAIT | | |
| Kubbar I. | | + |
| Ra's az Zawr | | + |
| MADAGASCAR* | | |
| Nosy Bé | | |
| Réserve Naturelle Intégrale de Lokobé | (IV) | |
| Nosy Tanikely "Marine Reserve" | + | |
| Nosy Ovambo | (+) | |
| Nosy Iranja | (+) | |
| Nosy Trozona | (+) | |
| Nosy Ve | (+) | |
| Chesterfield I. | (+) | |
| Grand Récif | | II |
| MALAYSIA | | |
| Pulau Tiga Park | II | |
| Tunku Abdul Rahman Park | II | |
| Turtle Islands Park | II | |
| Pulau Sipadan Marine Reserve | (IV) | + |
| Pulau Kapas Marine Park | F | + |
| Pulau Paya/Segantang/Lembu/Kaca Marine Park | F | + |
| Pulau Perhentian/Lang Tengah Marine Park | F | + |
| Pulau Redang Marine Park | F | + |
| Pulau Tenggol Marine Park | F | + |
| Pulau Tioman and adjacent islands Marine Park | F | + |
| Semporna National Marine Park | | + |
| Pulau Perak | | + |
| MALDIVES* | | |
| Ari Atoll | | IX |
| Felidhu | | + |
| Makunudu | | + |

Table 3 (Contd)

| | Established | Proposed/ Recommended |
|---|---|---|
| MALDIVES* (Contd) | | |
| Faadhippolhu | | + |
| Mulakatholhu | | + |
| North and South Nilandhe | | + |
| Hadhdhunmathi | | + |
| Kolhmadulu | | + |
| MAURITIUS | | |
| Black River Fishing Reserve | F | + |
| Flacq Fishing Reserve | F | + |
| Grand Port-Mahebourg Fishing Reserve | F | + |
| Ile aux Aigrettes Nature Reserve | (IV) | + |
| Ile Marianne Nature Reserve | (IV) | + |
| Port Louis Fishing Reserve | F | + |
| Rivière du Rampart-Poudre d'Or Fishing Reserve | F | + |
| Trou d'Eau Douce Fishing Reserve | F | + |
| Round Island Nature Reserve | (IV) | + |
| Coin de Mire Nature Reserve | (IV) | + |
| Rodrigues | | |
| Ile aux Cocos Nature Reserve | (IV) | |
| Ile aux Sables Nature Reserve | (IV) | |
| Ile Plate | (IV) | + |
| Ilot Gabriel | (IV) | + |
| Le Chaland/Blue Bay | | + |
| Baie de l'Arsenal | | + |
| Le Morne Brabant | | + |
| Flic en Flac | | + |
| Grande Baie | | + |
| Cargados Carajos Shoals | | + |
| Ile du Nord | (+) | |
| MOZAMBIQUE* | | |
| Parque Nacional do Bazaruto | + | |
| Ilhas da Inhaca e dos Portugueses Reserve | + | |
| Nacala-Mossuril | | + |
| Quirimba Is | | + |
| Primeiras and Segundos Is | | + |
| Paisley Seamount | | + |
| NORTH YEMEN* | | |
| Ra's Isa | | + |
| Zuqur Is | | + |
| Al Luhayyah | | + |
| Uqban | | + |
| 6 sites between Al Khawkhah to Dhubab | | + |
| Zubayr Is | | + |
| PHILIPPINES* | | |
| (° = never implemented; areas declared as Marine Reserves and Tourist Zones under PD 1801 of 1978 are not listed) | | |
| Hundred Is National Park | (+) | |
| Puerta Galera Biosphere Reserve | IX | |
| Santa Cruz Is National Park° | V | |
| Sumilon I. Marine Reserve and Fish Sanctuary | + | |
| Fuga I. Underwater Museum° | + | |
| Camiguin I. Marine Sanctuary° | + | |
| Guiuan Peninsula Marine Sanctuary° | + | |
| Nasugbu Marine Sanctuary° | + | |
| Panguil Bay Marine Sanctuary° | + | |
| Polillo Is Marine Sanctuary° | + | |

Table 3 (Contd)

| | Established | Proposed/ Recommended |
|---|---|---|
| PHILIPPINES* (Contd) | | |
| Turtle Is Marine Sanctuary° | + | |
| Carbin Reef Municipal Park | + | |
| Guindulman Municipal Marine Reserve | + | |
| Apo Island Municipal Reserve | + | |
| Balicasag Municipal Reserve | + | |
| Pamilacan Municipal Reserve | + | |
| Sicogon I. Municipal Marine Park | | + |
| Moalboal/Pescador I. Municipal Park | | + |
| Panglao Municipal Reserve | | + |
| Apo Reef Marine Park | | + |
| Sombrero I. Marine Park | | + |
| Fortune I. | | + |
| Mactan I. | | + |
| Santiago/Silaqui I. | | + |
| Danajon Bank Marine Park/Reserve | | + |
| Dos Hermanas Marine Park/Reserve | | + |
| Tubbataha Reef | | + |
| Monomoc Is, Cuyo Group | | + |
| San Miguel I. | | + |
| Palawan Game and Bird Sanctuary, Mangrove Swamp Forest Reserve, offshore island Nature Reserves | (+) | |
| Malampaya Sound° | F | + |
| Cagayan Is | (+) | |
| Caluit I. | (+) | |
| El Nido Marine Park | | + |
| Honda Bay Marine Park | | + |
| Port Barton Marine Park | | + |
| Kalayaan Is | (+?) | + |
| QATAR* | | |
| REUNION* | | |
| Réunion | | |
| Lagoon | F | |
| 3 "réserves tournantes" | F | |
| Europa Réserve Naturelle | IV | |
| Tromelin Réserve Naturelle | IV | |
| Bassas de India Réserve Naturelle | IV | |
| Iles Glorieuses Réserve Naturelle | IV | |
| SAUDI ARABIA* - RED SEA COAST | | |
| Humaydah area | | + |
| Ras Suwahil area | | + |
| Maqna North Beach | | + |
| Tiran Islands | | + |
| Al Muwailih | | + |
| Sharm Yahar to Sharm Jubba | | + |
| Sharm Zubeir | | + |
| Coastline south of Sharm Zubbeir | | + |
| Ghubbet Bal'aksh | | + |
| Sharms Dumagha and Antar | | + |
| Sharms Habban and Munaibira | | + |
| Wajh Bank and islands | | + |
| Qalib Islands | | + |
| Umm Lajj | | + |
| Al Hasani, Libana, Maliha and Umm Sihr Islands | | + |
| Ras Abu Madd to Sharm Hasi | | + |
| Sharm al Khaur | | + |
| Sharm Yanbu | | + |
| Yanbu City Conservation Area | | + |

Table 3 (Contd)

| | Established | Proposed/ Recommended |
|---|---|---|
| SAUDI ARABIA* - RED SEA COAST (Contd) | | |
| Shi'b Green Reef Complex | | + |
| Marsa al Usalla | | + |
| Mersa Tawil | | + |
| Mastura Beach | | + |
| Mersa as Sarraj | | + |
| Marsa umm Misk | | + |
| Haramil Island | | + |
| Ra's Hatibah | | + |
| Jiddah Salt Marsh | | + |
| Shu'aiba | | + |
| Abu Duda lagoon/Asir National Park | | + |
| Qishran Island | | + |
| North Inner Farasan Bank reefs and islands | | + |
| South Al Qunfudhah | | + |
| Khor Amiq and Raka | | + |
| Khor Nahud | | + |
| Marqa Island | | + |
| North and South Sharm Wasm | | + |
| Khor Itwad | | + |
| Khawr al Ja'afirah area | | + |
| North Outer Farasan Bank reefs and islands | | + |
| Farasan Archipelago | | + |
| Shi'Abu Al Liqa | | + |
| Shi'b Al Kabir | | + |
| South Jizan Beach | | + |
| Khor al Wahla | | + |
| Oreste Point | | + |
| SAUDI ARABIA - GULF COAST | | |
| Karan | | + |
| Kurayn | | + |
| Jana | | + |
| Al Jurayd | | + |
| Harqus | | + |
| Al Arabiyah | | + |
| Tarut Bay Complex | | + |
| Abu Ali/Dawhat and Dafi/Musallamiyah Complex | | + |
| Al'Uqayr Bay | | + |
| Southern Gulf of Salwah | | + |
| Safaniya/Manifa Bay Complex | | + |
| SEYCHELLES* | | |
| Curieuse Marine National Park | II | |
| St Anne Marine National Park | II | |
| Port Launay Marine National Park | II | |
| Baie Ternay Marine National Park | II | |
| Shell reserves, Mahé: | | |
| North-east Pt-Anse Nord d'Est | + | |
| South-east I.-Pte au Sel | + | |
| Shell reserve, La Digue | | |
| La Passe-Cap Bayard R. | + | |
| Shell reserve, Praslin | | |
| Anse Boudin-Pte Zanguilles | + | |
| Aldabra Atoll Special Reserve | I/X | |
| Cousin Island Special Reserve | I | |
| Aride Island Special Reserve | (I) | + |
| Beacon (Ile Sèche) | (IV) | |
| Booby (Ile aux Fous) | (IV) | |
| Boudeuse | (IV) | |
| Etoile | (IV) | |

Table 3 (Contd)

| | Established | Proposed/ Recommended |
|---|---|---|
| SEYCHELLES* (Contd) | | |
| King Ross (Lamperiaire) | (IV) | |
| Les Mamelles | (IV) | |
| Vache Marine | (IV) | |
| La Digue National Park | | + |
| Desnoefs I. | | (+) |
| African Banks | | (+) |
| Bird Island (Ile aux Vaches) | | (+) |
| Récif Island | | (+) |
| Frégate | | (+) |
| Felicité | | (+) |
| Cosmoledo | | (+) |
| Cousine | | (+) |
| Albatross Rocks/Cocos Isands | | + |
| SINGAPORE | | |
| Labrador Park Nature Reserve | (+) | |
| Southern Islands | | + |
| SOMALIA | | |
| Lac Badana National Park and Bajuni Archipelago | | + |
| Muqdisho coastal area | | + |
| SOUTH AFRICA | | |
| St Lucia Marine Reserve | IV | |
| SOUTH YEMEN* | | |
| Ra's Abu Quizara | | + |
| Perim I. | | + |
| Socotra I. | | + |
| Nishtun | | + |
| SRI LANKA* (° = never implemented) | | |
| Hikkaduwa Marine Sanctuary | IV | + |
| Mount Lavinia Lobster Reserve° | VI | |
| Ruhuna National Park | (II) | |
| Great and Little Basses Reefs Marine Sanctuary | | + |
| Pigeon I. Marine Sanctuary | (IV) | + |
| Polhena Reef Marine Sanctuary | | + |
| Pasekudah and Kalkudah Bay Marine Sanctuary | | + |
| Wilpattu National Park and Dutch Bay | (II) | + |
| Thennadi Bay | | + |
| SUDAN* | | |
| Gebel Elba Conservation Area | + | |
| Sanganeb Marine National Park | | + |
| Port Sudan Marine National Park | | + |
| Suakin Archipelago | | + |
| Mukkawar Island and Dunganab Bay | | + |
| Wreck of the "Umbria" | | + |
| Wingate Reef | | + |
| Shaab Rumi | | + |
| SULTANATE OF OMAN* | | |
| Musandam Peninsula - 15 Nature or Scenic Reserves | | + |
| Ra's as Sawadi National Recreation Area and Scenic Reserve | | + |
| Jaza'r Daymaniyat Bird Sanctuary and | (IV) | |
| National Nature Reserve | | + |

Table 3 (Contd)

| | Established | Proposed/ Recommended |
|---|---|---|
| SULTANATE OF OMAN* (Contd) | | |
| Qur'm Public Park and Nature Reserve | (IV) | |
| Qur'm-Al Fahl National Nature Reserve | | + |
| Bandar Jissah National Scenic Reserve and Recreation Area | | + |
| Bandar Khayran National Nature Reserve | | + |
| Ra's Abu Da'ud National Scenic Reserve | | + |
| Jabal Bani Jabir National Scenic Reserve | | + |
| Jazirat Masirah - 3 National Nature Reserves | | + |
| Barr al Hikman National Nature Reserve | | + |
| Az Zahr National Scenic Reserve | | + |
| Kuria Muria Is - 4 National Nature Reserves | | + |
| Sadh National Nature Reserve | | + |
| Mirbat National Nature Reserve | | + |
| TANZANIA* | | |
| (° = never implemented) | | |
| Dar es Salaam Reefs | | |
| Mbudya Marine Reserve° | + | |
| Bongoyo Marine Reserve° | + | |
| Pangavini Marine Reserve° | + | |
| Fungu Yasini Marine Reserve° | + | |
| Mafia I. | | |
| Chole Bay Marine Reserve° | + | |
| Tutia Island Marine Reserve° | + | |
| Tanga Coral Gardens Marine Reserve° | + | |
| Maziwi I. Marine Reserve° | + | |
| Latham Island | | + |
| Prison I., Zanzibar | | + |
| THAILAND | | |
| Moo Ko Similan National Park | II | |
| Moo Ko Surin National Park | VI | |
| Hat Nai Yang National Park | II | |
| Phangnga Bay National Park | II | |
| Hat Nopharat Thara-Moo Ko Pipi National Park | II | |
| Tarutao National Park | II | |
| Khao Laem Ya-Mu Ko Samet National Park | V | |
| Moo Ko Ang Thong National Park | IV | |
| Khao Sam Roi Yot National Park | II | |
| Ko Lan, Ko Sak, Ko Krok | | + |
| UNITED ARAB EMIRATES | | |

**IUCN categories and management objectives of protected areas**

I *Scientific Reserve/Strict Nature Reserve*: To protect nature and maintain natural processes in an undisturbed state in order to have ecologically representative examples of the natural environment available for scientific study, environmental monitoring, education, and for the maintenance of genetic resources in a dynamic and evolutionary state.

II *National Park*: To protect natural and scenic areas of national or international significance for scientific, educational, and recreational use.

III *Natural Monument/Natural Landmark*: To protect and preserve nationally significant natural features because of their special interest or unique characteristics.

IV *Managed Nature Reserve/Wildlife Sanctuary*: To assure the natural conditions necessary to protect nationally significant species, groups of species, biotic communities, or physical features of the environment where these require specific human manipulation for their perpetuation.

Table 3 (Contd)

| | |
|---|---|
| V | *Protected Landscape or Seascape*: To maintain nationally significant natural landscapes which are characteristic of the harmonious interaction of man and land while providing opportunities for public enjoyment through recreation and tourism within the normal life style and economic activity of these areas. |
| VI | *Resource Reserve*: To protect the natural resources of the area for future use and prevent or contain development activities that could affect the resource pending the establishment of objectives which are based upon appropriate knowledge and planning. |
| VII | *Natural Biotic Area/Anthropological Reserve*: To allow the way of life of societies living in harmony with the environment to continue undisturbed by modern technology. |
| VIII | *Multiple-Use Management Area/Managed Resource Area*: To provide for the sustained production of water, timber, wildlife, pasture, and outdoor recreation, with the conservation of nature primarily oriented to the support of the economic activities (although specific zones may also be designated within these areas to achieve specific conservation objectives). |
| IX | *Biosphere Reserve*: To conserve for present and future use the diversity and integrity of representative biotic communities of plants and animals within natural ecosystems, and to safeguard the genetic diversity of species on which their continuing evolution depends. |
| X | *World Heritage Site*: To protect the natural features for which the area was considered to be of World Heritage quality, and to provide information for world-wide public enlightenment. |

# TABLE 4: NATIONAL LEGISLATION RELATING TO CORAL REEFS

This list is known to be incomplete but has been included as a guide to the types of legislation which exist for the management of coral reefs and reef fisheries. Information was not obtained for Bahrain, Bangladesh, Brunei, Burma, Pakistan, South Yemen, United Arab Emirates and Vietnam, but is available from other sources, such as the IUCN Environmental Law Centre, Bonn, West Germany. Further information on Eastern African countries is given in FAO/UNEP (1983). Corrections and additions should be sent to the compiler.

AUSTRALIA - WESTERN
State Fisheries Act, 1954.
Pollution, fisheries and protected areas legislation exists but details have not been obtained.

CHAGOS
Ordinance 2, 1968 (S.I. No. 11).
- gives powers to the British Indian Ocean Territory Commissioner to make regulations for the preservation of wildlife; bans collection, possession and sale of Green Turtles.

COMOROS
- fishing with dynamite and poison prohibited.
- Dugong protected.
- coral and sand removal controlled.

Mayotte (under French legislation)
- Law 60.708, 1960 establishes National Parks.
- Loi sur la Protection de la Nature, 1976, covers environmental protection.
- fishing with poison is prohibited.
- (two year moratorium on spearfishing 1977-1979 now lifted.)

DJIBOUTI
Arrêté No. 72-1363 SG/CG.
- designates a number of reserves with coral reefs within which fishing is prohibited except by traditional methods and shell and coral collecting is banned.

Décret No. 80-062/PR/MCTT, 1980.
- designates Ile Maskali reserve; prohibits (until further notice) the export of reef fish, collection of shells, and collection, sale and export of dugong, turtles and their eggs; restricts spearfishing.

Decree, 1985.
- bans spearfishing.

EGYPT
Pollution legislation passed in 1962, revised in 1983.
Collection of corals, shells and other marine animals, spearfishing, and taking of marine fish prohibited in mainland Red Sea Province and on Sinai coast to south of El Tur.
Conservation Law 102, 1983.
- provides for the creation of marine protectorates.

Prime Minister's Decree 1067, 1983.
- provides for the implementation of Law 102.

Prime Minister's Decree 1068, 1983.
- establishes regulations for Ras Muhammad, Tiran and Sinafir protectorates.

Prime Minster's Decree 450, 1986.
- establishes Gebel Elba Conservation Area.

Sinai Peninsula - South Sinai Governorate:
- Decree 15, 1980, prohibits fishing and removal of species from reefs from Ras Muhammad to Taba in east and El Tur in west; hunting and fishing may be permitted under certain conditions.
- Decree 472, 1982, prohibits hunting in certain parts of Sinai and taking of fish (including shells, oysters, corals and other marine creatures) by nets or dynamite, from Taba to Ras Muhammad.

ETHIOPIA
Proclamation No. 137, 1978.
- prevents marine pollution.

INDIA
Wildlife Act, 1972.
- protects marine species including turtles, Saltwater Crocodiles, Dugong, Coconut Crab.
- provides for establishment of protected areas.

Chank Fisheries Act.
- controls chank fishery.

Pearl Fisheries Ordinance.
- controls pearl oyster fishing.

Legislation exists to control oil pollution.

INDONESIA
Protected areas are declared under Ministerial decrees (see section on Indonesia).
There are several fishing regulations including:
Fishery Ordinance, 1920.
- prohibits destructive fishing methods, including use of explosives and dynamite.
- prohibits harvest of pearls and sponges.

Provincial regulations, Kepulauan Seribu.
- control coral and sand mining.

Early Dutch legislation restricts exploitation of live corals including mining and requires permits.
Ministerial Decrees.
- protect Loggerhead, Leatherback and Olive Ridley Turtles, Dugong and Saltwater Crocodile.

Traditional "adat" control exploitation of marine resources in several areas.

IRAN
Environmental Protection and Enhancement Act, 1974.

ISRAEL
Pollution, fisheries and protected areas legislation exists but details have not been obtained.

JORDAN
Ministry of Agriculture Law 20, 1973 (items 180-186).
- controls fisheries.
- prohibits coral collecting, spearfishing, dynamiting.

Ship Act 25, 1975.
- prohibits disposal of chemicals and toxic products, including oil, into the sea.

Protected areas legislation exists.

KENYA
Wildlife (Conservation and Management) Act, 1976,

Legal Notice 219
- designates National Parks and Reserves.

A quota system for shell collecting exists.

KUWAIT
Fishing regulations exist.

MADAGASCAR
Protected areas legislation is considered to apply to terrestrial areas only.
Resolution 23.5.23.
- protects turtles in five areas.

Decree, 23.8.29.
- imposes controls on collection of pearl oysters, mother-of-pearl shells and sponges.

Decree, 27.12.62.
- establishes closed season for spiny lobsters, prohibits collection of berried females.

MALAYSIA
National Land Code Act 56, sect. 62, 1965.
- establishes marine conservation areas at State level.

Fisheries (Protected Areas) Regulations, 1983.
- permits protection of reef areas from fishing.

Peninsular Malaysia - National Parks Act No. 226.
- establishes National Parks.

Peninsular Malaysia - Wildlife Act, 1972.
- establishes Wildlife Sanctuaries and Reserves.

Peninsular Malaysia - Fisheries Act 1985.
- establishes and manages marine parks.

Sabah - National Parks Ordinance, 1962, replaced by Parks Enactment Act, 1984.
- establishes National Parks.

MALDIVES
- minimum size for turtles; turtle shells may only be exported as a worked product.
- black coral may only be exported as a worked product.
- minimum size for spiny lobsters.
- import of spearguns prohibited; use of spearguns may be prohibited.
- controls on coral mining.
- quota for collection of aquarium fish.

MAURITIUS
Fisheries Act, 1980 and Fisheries Regulations, 1983.
- prohibit take of undersized or berried spiny lobsters, use of poisons and explosives, import or export without a permit of live fish, corals and shells, whether dead or alive, collection of turtles and marine mammals; specify licence quotas for certain areas; define six fishing reserves within which large net or gill net fishing is prohibited.

Visitors may take up to six shells each, provided an export permit is obtained.
Spearfishing is prohibited.
Ancient Monuments Act, 1944 and Forest and Reserves Act, 1983.
- provide for establishment of protected areas.

(See section on Mauritius for further information on coastal legislation.)

MOZAMBIQUE
Decree 40040, 1955.
- provides for establishment of protected areas.

Hunting Law 7, 1978 and Decree 117, 1978.
- protect marine turtles.

Corals are protected or controlled but details of this legislation have not been obtained.

NORTH YEMEN
Law No. 20, 1978.
- controls fisheries; provides permit system; bans use of explosives and toxins.

Law No. 13, 1976.
- identifies protocol for forbidding discharge of oil, ballast, rubbish and other harmful substances.

PHILIPPINES
Presidential Decree 1219, 1977.
- prohibits collection, sale and export of coral, except under certain conditions.*

Presidential Decree 1698, 1980.
- jurisdiction of all coral resources given to Bureau of Fisheries and Aquatic Resources.
- prohibits collection of corals.*

Destructive fishing methods, particularly dynamiting and, since 1986, muro-ami, are illegal.
Presidential Decree, 1980.
- bans collection of turtles and eggs, and export of turtles.

Presidential Decree, 1970.
- declares a number of marine sanctuaries.

Presidential Proclamation 1801, 1978.
- declares tourist zones and marine reserves under the administration of the Philippine Tourism Authority.

Several other Presidential Decrees declare protected areas.
A number of recent Municipal Orders establish municipal marine parks or conservation areas.

* In May 1986 the ban on coral exploitation was lifted for one year.

QATAR
Law 4, 1981.
- establishes Environment Protection Committee.

Law 4, 1985.
- covers protection and utilization of Living Sea Resources.

REUNION
Circulaire du 26.8.80 relative à l'utilisation des terraines dominiaux du littoral dans les départements d'outre-mer.
- provides for management of coastal zone.

National Park Law 60.708, 22.8.60.
- provides for establishment of national parks.

Loi sur la Protection de la Nature, 10.7.76.
- covers aspects of environmental protection.

Décret 78148, 3.2.78.
- covers the EEZ.

Arrêté 2862, 21.7.76.
- prohibits dynamite or poison for fishing.
- sets size limits and close seasons for fish and lobsters (close season of 1 Jan. to 31 Mar. for lobsters).
- prohibits collection of living corals and molluscs other than mussels.

Arrêté 1486, 1969.
- prohibits collection of coral from lagoon but permits coral sand extraction from dunes and dead coral from beaches.

Arrêté 1904, 25.5.76.
- prohibits spearfishing 1 Oct.-31 Dec., at night, within reserves, and for spiny lobster, coral and shells.

Turtles are protected.
Arrêté 1905, 25.5.76.
- declares the lagoon a fishing reserve and establishes "réserves tournantes".

Arrêté 13, 18.11.75.
- declares Réserves Naturelles at Europa, Bassas de India, Iles Glorieuses and Tromelin.

SAUDI ARABIA
Minimum size limits for some fish species.
New legislation for environmental issues in preparation including legislation to establish marine protectorates.

SEYCHELLES
Fishing is regulated.
- use of dynamite and spearfishing prohibited.

Turtles (Protection) Regulations S.I. 115, 1979.
- revokes earlier turtle laws and protects all marine turtles.

Conservation of Marine Shells Act, 1981.
- bans collection of shells from shell reserves, as designated, except dead shells on the foreshore.
- bans collection anywhere of listed protected species.
- limits collection of other shells to 20 kg a day.
- prohibits sale and purchase of unworked shells and of unworked and worked shells of protected species.
- prohibits export of shells for commercial purposes.
- revokes earlier shell laws.

National Parks and Nature Conservance Ordinance, 1969, and subsequent amendments.
- provides for establishment of protected areas.

Wild Animals and Birds (Protection) Ordinance, 1961, and Wild Birds (Protection) Regulations, 1966.
- provide for establishment of nature reserves.

(See section on Seychelles for further information on coastal legislation.)

SINGAPORE
The Nature Reserves Act does not cover the marine environment.
(Information on pollution and fisheries legislation has not been obtained.)

SOMALIA
Tourism Act, 1984.
- provides for protection of the environment and for planning of marine protected areas.

Maritime Code - Decree 1, 31.2.59, amended by Decree 7, 1.11.66.
- fishing only permitted under concession from Ministry of Fisheries.
- prohibits dynamite, electric current, chemical etc. fishing methods.
- allows for prohibition of fishing in certain areas.

SOUTH AFRICA
Comprehensive protected areas, fisheries and pollution legislation exists but information has not been obtained; all reefs lie within proclaimed protected areas.

SOUTH YEMEN
Laws exist concerning the marine environment, coastal zone and fishing.
- discharge of oil, ballast, rubbish and other harmful substances into the marine environment is prohibited.

Law 24, 1979
- prohibits use of toxic, explosive or chemical substances for the purpose of fishing.

SRI LANKA
National Environment Act No. 47 of 1980.
National Aquatic Resources Research and Development Agency Act No. 54, 1981.
Fisheries Ordinance.
- prohibits take of berried, soft-shelled or undersized lobsters.

Fisheries Amendments Law 20, 1973.
- bans use of dynamite, and possession of fish killed by dynamite or poison.

Import of spearguns is prohibited.
Ordinances control fishery for chanks and pearl oysters.
Coast Conservation Act No. 57, 1981.
- mandates Coast Conservation Division to prepare coastal zone management programme; provides CCD with authority to review development plans within coastal zone.

Fauna and Flora Protection Ordinance, 1937.
- regulates hunting; provides for establishment of protected areas.

SUDAN
Environmental Health Act, 1975.
- prohibits discharge of poisonous substances into the sea.

Marine Fisheries Regulations, 1937, and Amendments, 1975.
- prohibits use of spearguns, collection of corals, shells and aquarium fish, and disposal of refuse in sea.

Local Order, Commissioner of Red Sea Province.
- prohibits trade in corals, shells and aquarium fish.

Marine Fisheries Act and Marine Environment Conservation Act, shortly to be implemented.
- provides for establishment of marine parks and reserves.
- regulates construction in or near the sea.

SULTANATE OF OMAN
Royal Decree 34, 1974.
- provides for control of marine pollution.

Royal Decree 26, 1979.
- provides for establishment of National Parks and Protected Nature Reserves.

Royal Decree 53, 1981: Law of Sea Fishing and Protection of Marine Biological Wealth.
- restricts use of potentially destructive fishing gear and fishing operations in certain areas; provides for protection of marine mammals and turtles.
- prohibits spearfishing.

Royal Decree, 1976.
- controls take of spiny lobsters.

Royal Decree 10, 1982.
- provides for protection of the environment and the prevention of pollution.

Ministry of Agriculture and Fisheries Regulations.
- prohibit collection of live molluscs.

New legislation for marine resources is being prepared.

TANZANIA
Wildlife Conservation Act, 1974.
- provides for establishment of protected areas.

THAILAND
Fisheries Acts B.E. 2490, 1947 and B.E. 2496, 1953 with 1972 Amendments.
- provides some regulations for marine fisheries; protects Dugong, and Hawksbill, Loggerhead and Green Turtles; prohibits use of dynamite and poisons; prohibits trawling within 3 km of the coast.

Coral collection is prohibited.

National Parks Act B.E. 2504, 1961.
- provides for the establishment of National Parks.

# AUSTRALIA, WESTERN

## INTRODUCTION

### General Description

The portion of Western Australia off which coral reefs occur extends over 3000 km between the southernmost reef development at the Houtman Abrolhos and the State's northern border. A wide variety of coral reef types are found, reflecting, to a greater or lesser extent, the effect of the continent on reef development. They range from open ocean atolls, related to Australia only by political ties (Cocos-Keeling and Christmas Island), to fringing and veneer reefs on drowned coastal formations (Kimberley Coast, Pilbara Coast, Barrow and Monte Bello Is). They include continental shelf atolls and platform reefs of varying degrees of development, perfection and isolation (Ashmore, Scott, Seringapatam reefs, Rowley Shoals and the Abrolhos reefs), and an extensive barrier/fringing reef tract (Ningaloo).

Three fundamental parameters have interacted to produce this variety. Firstly, the geological structure and history of the coast is characterized by sedimentary forms pierced by igneous intrusions. These have been shaped through geological time by a series of marine transgressions across broad areas of the continental margin. Secondly, climatic conditions became less tropical during the Holocene, resulting in arid semi-deserts throughout much of the land area. Consistent onshore winds and winter rainfall characterize the southern region from the Abrolhos to Dampier, while a monsoonal weather pattern with a well-defined cyclone season brings summer rains further north. Thirdly, the hydrodynamic environment includes the unique features of a south-flowing tropical current along the western shelf edge (the Leeuwin Current) and extremely high amplitude tides in the northern regions.

These factors have produced a complex coastal morphology which has provided numerous foundations for reef growth during transgressive phases. The foundations for reef development during the Holocene are often relict reefs of Pleistocene origin. The best examples are the Houtman Abrolhos, to which the Leeuwin current delivers warm water and the larvae of tropical species, thereby sustaining these high latitude reefs. Coral communities are also found on the south-west mainland coast around Rottnest Island and in Jurien Bay (Stoddart, 1984) and isolated scleractinian colonies occur as far south as Cape Naturaliste. Shark Bay, Australia's largest enclosed bay, has irregular fringing reefs surrounding the arc of continental islands enclosing the western side of the bay. The tidal range is very small, leaving pockets of very saline water in the southern parts of the bay which probably restricts coral growth, but which has resulted in the presence of algal stromatolites (Veron, 1986b).

Arid conditions further north produce little terrestrial runoff, allowing spectacular reef development in close proximity to the coast (e.g. the Ningaloo Reef Tract, the largest fringing reef in Australia). Further north, the broad North-West Shelf supports numerous excellent examples of shelf edge atolls such as the Rowley Shoals, while the inshore areas feature numerous islands with fringing and platform reefs such as occur in the Dampier Archipelago; the latter reefs are largely submerged and exist in turbid water stirred by strong tidal currents. The Kimberley and far north-western coastlines are characterized by rugged terrain and a shallow continental shelf. Coastal embayments, mangals and numerous creeks and rivers combine with high tidal amplitude to produce turbid conditions for the coastal reefs of the far north such as the Lacepedes and the Buccaneer Achipelago. In the Timor and Arafura Seas, extensive reefs occur only towards the Indonesian Archipelago, beyong the Sahul Shelf, such as Scott and Seringapatam reefs (Veron, 1986b).

### Reef Resources

The small human population of just over a million is concentrated in the south of the state, and access to most of the coast where reefs occur is limited by poor roads. The exceptions are the Ningaloo Reef Tract, which is receiving rapidly increasing exploitative and recreational use in certain areas, the Houtman Abrolhos which have a long history of extensive exploitation (*see separate accounts*), and certain reefs of the Pilbara region which is undergoing industrial development. The extent and variety of coral reefs in Western Australia makes it inevitable, and acceptable, that some will be affected by human activities.

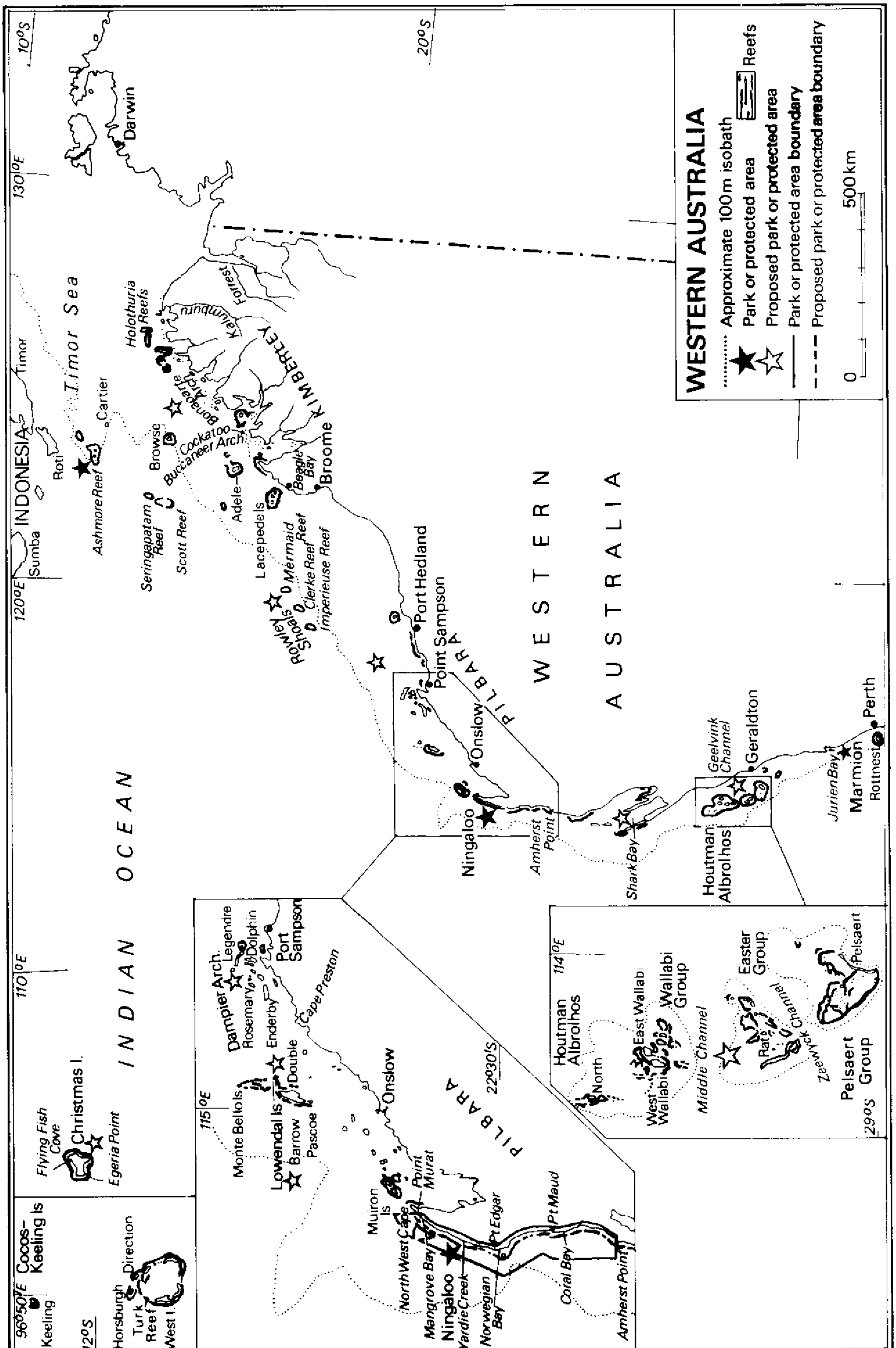
### Disturbances and Deficiencies

With few exceptions the reefs of Western Australia are in pristine condition. Activities which have a deleterious effect in some areas (such as poaching by foreign fishermen) are described in the following accounts. Some of the more distant reefs such as Ashmore and Christmas Island are used by indigenous peoples for extractive purposes.

### Legislation and Management

The majority of reefs fall under state jurisdiction although the Commonwealth Government has responsibility for some important areas such as the Indian Ocean reefs (Cocos-Keeling and Christmas Island), Ashmore Reef, the Monte Bello Islands and Imperieuse Reef in the Rowley Shoals. The only protected areas which include reefs are Ashmore Reef National Nature Reserve and Ningaloo Marine Park (*see separate accounts*). Marmion Marine Park, which stretches from 20 to 40 km north of Perth along the coast, was established in 1986, and includes major coral communities but has no true reef formations (Wilson, 1986).

Conservation policy and legislation for the protection and management of Western Australian reefs was virtually non-existent until 1985, with the exception of a small portion of the Ningaloo Reef and Ashmore Reef. The Conservation and Land Management (CALM) Act of 1985 allows for the progressive transfer of authority over reef areas from departments concerned primarily with exploitation such as the Department of Fisheries, to


WESTERN AUSTRALIA
Approximate 100m isobath
Park or protected area
Proposed park or protected area
Park or protected area boundary
Proposed park or protected area boundary
Reefs
0
500km
10°S
20°S
130°E
120°E
110°E
INDONESIA
Timor
Timor Sea
Sumba
Roti
Darwin
Ashmore Reef
Cartier
Browse
Seringapatam Reef
Scott Reef
Adele
Lacepede Is
Holothuria Reefs
Bonaparte Arch.
Cockatoo
Buccaneer Arch.
KIMBERLEY
Forrest
Kalumburu
Beagle Bay
Broome
Mermaid Reef
Clerke Reef
Imperieuse Reef
Rowley Shoals
Port Hedland
Point Sampson
PILBARA
Onslow
Ningaloo
Amherst Point
Shark Bay
Houtman Albrolhos
Geelvink Channel
Geraldton
Jurien Bay
Marmion
Rottnest
Perth
WESTERN AUSTRALIA
INDIAN OCEAN
96°50'E
Cocos-Keeling Is
Keeling
Horsburgh
Direction
Turk Reef
West I.
12°S
Flying Fish Cove
Christmas I.
Egeria Point
115°E
Dampier Arch.
Legendre
Dolphin
Rosemary
Enderby
Port Sampson
Cape Preston
Double
Lowendal Is
Barrow
Pascoe
Monte Bellos
Onslow
22°30'S
PILBARA
Muiron Is
Point Murat
North West Cape
Mangrove Bay
Ningaloo
Yardie Creek
Norwegian Bay
Pt Edgar
Pt Maud
Coral Bay
Amherst Point
114°E
Houtman Albrolhos
North
East Wallabi
West Wallabi
Wallabi Group
Middle Channel
Easter Group
Rat I.
Zeewyck Channel
Pelsaert
Pelsaert Group
29°S

conservation-based organisations such as the Department of Conservation and Land Management. This initiative has the potential to provide a comprehensive approach to the conservation and management of the reefs. Recently a Marine Parks and Reserves Selection Working Group has been established.

**Recommendations**

There are numerous terrestrial reserves which could be used to control access by land to nearby reefs and as the basis for extending protection below the littoral zone. In areas where reefs occur beyond the 3 n. mi. limit of state territorial jurisdiction, co-operation with the Commonwealth Government is required. There have been a number of recent proposals from conservation bodies such as the Australian Conservation Foundation and the Western Australian Coral Reef Association for the creation of marine reserves which incorporate multiple use zoning plans, such as Ningaloo Reef and the Houtman Abrolhos.

Marine extensions of the boundaries, to include the reefs, or some other form of protection for the marine environment, have been recommended for the following terrestrial protected areas (*see separate accounts*):

Barrow Island Reserve
Christmas Island National Park
Dampier Archipelago Reserves
Kimberley coast Reserves
Houtman Abrolhos Islands Reserves
Lowendal Islands Nature Reserve

It has been recommended that the reefs surrounding the Muiron Islands Reserve should be included in the Ningaloo Marine Park (*see separate accounts*). The reefs surrounding the Monte Bello Islands have been recommended for protection and a proposal for the establishment of Marine Nature Reserves at Rowley Shoals has been made (*see separate accounts*). The Shark Bay region has been recommended as a large marine/terrestrial National Park and has potential for listing as a World Heritage Site (Nevill and Lawrence, 1984). Further work is required at Cocos-Keeling, Scott and Seringapatam Reefs (*see separate accounts*) to determine a management strategy for these reefs.

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## ASHMORE REEF NATIONAL NATURE RESERVE

**Geographical Location** Timor Sea, 850 km west of Darwin, 640 km north-north-east of Broome and 350 km off the Kimberley coast of North-Western Australia; 12°10-12°20'S, 122°53-123°16'E.

**Area, Depth, Altitude** 583 sq. km, including Ashmore Reef and the surrounding seas to approximately the 50 m depth contour. The reef is approximately 25 km x 13.75 km (150 sq. km) with three low vegetated sand cays, West Island (approx. 1400 x 500 m, 32 ha), Middle Island (approx. 1200 x 400 m, 13 ha) and East Island (approx. 800 x 600 m, 16 ha) (Forbes, 1982). The sand cays have a maximum height of 2.5 m.

**Land Tenure** Australian Commonwealth Government as part of the Territory of Ashmore and Cartier Islands.

**Physical Features** Ashmore is a platform reef with extensive areas of coral reef and sand banks (Forbes, 1982). It rises from an outlier of the north-western margin of the Sahul Shelf and is separated from it by a narrow channel about 280 m deep. The shelf to the east is less than 100 m deep but to the north-west and south-west of Ashmore Reef the bottom drops away steeply. Fairbridge (1950, 1953 and 1971) and Teichert and Fairbridge (1948) discuss the geomorphology of the Sahul Shelf and some of the reefs and islands including Browse and Cartier but not specifically Ashmore Reef.

The three islands have a low foredune with a slightly depressed interior consisting of sandy soils. Occasional limestone outcrops fringe the shoreline of West Island (Hicks, 1983; Sarti, 1983); Serventy (1952) noted limestone pavement around part of the shoreline of Middle Island. Forbes (1982) and Hicks (1983) provide sketch maps of the vegetation, distribution of fauna and human use of the islands. The reef flats and many sand banks are emergent at low tide.

The climate is monsoonal with south-east trade winds between April and October and a north-west or west monsoon prevailing between November and March. The months of October-November and March-April are periods of transition characterized by an alternation of doldrums and sudden squalls. The north-west monsoon is rainbearing, the south-east monsoon dry (Fairbridge, 1950). No rainfall figures are available. Ashmore Reef lies to the north of the main belt of tropical cyclones with only one passing close to it between 1975 and 1982 (Western Australian Yearbook, 1983). Wave action is unrecorded but it is probably similar to that of Scott Reef, which is less than at the Rowley Shoals. Tidal range was estimated by Serventy (1952) to be about 3.7 m at springs. Hicks (pers. comm.) has calculated a maximum range of 3.9 m. The islands can only be approached at more than half tide.

**Reef Structure and Corals** Until 1986, little was known of the reef and nothing of the coral fauna. The results of the 1986 Western Australian Museum survey are currently being written up but the reefs are considered to be similar to Rowley Shoals (Berry *in litt.*, 4.11.86). The "Professor Bogorov" Expedition (1978) provided some habitat data for the reefs north-west of West Island and north of East Island. Habitats included intertidal reef flat, with coral slabs and stones; "lagoon" (1.5 to 7 m), sand with occasional patches of turtle grass, Alcyonacea or scattered small patches of coral; "lagoon" (15 m), silty sand, turbid water, and patch reefs 3-5 m high; outer reef slope, buttress zone (5-8 m), coral slabs with algae and hydroids; outer slope and first terrace at 12-14 m (5-15 m), slabs and stones on the slope, sand and rare patch reefs on the terrace (Anon., 1978a). Coral slopes of Ashmore Reef are illustrated in Dunson (1975); Heatwole (1975) and McCosker (1975) and have good coral cover. Four genera of Alcyonacea, *Sinularia, Sarcophyton, Capnella* and *Litophyton* were collected by the "Professor Bogorov" Expedition.

**Noteworthy Fauna and Flora** Ashmore Reef, particularly West Island is a nesting site for Green Turtle *Chelonia mydas* (Forbes, 1982; Hicks, 1983; Sarti, 1983). A Hawksbill Turtle *Eretmochelys imbricata* was observed at East Island (Hicks, 1983). *Dugong dugon* has been reported at West Island (Hicks, 1983). Twelve species of sea snakes (Hydrophiidae) have been recorded from Ashmore Reef (Cogger, 1975), and it is the type locality for two species (Smith, 1926).

The islands support a large avian fauna of 39 species of breeding and migratory birds including 18 waders and eight species of breeding sea birds particularly Sooty Terns *Sterna fuscata* and Noddies *Anous* spp. (Hicks, 1983; Serventy, 1952). Fifty-six species of echinoderms were collected during the "Professor Bogorov" Expedition, 26 of which were holothurians including seven beche-de-mer species. *Microthele nobilis*, the species preferred in commerce, was not among them. The echinoderm fauna has reef species in common with Scott Reef but includes a higher proportion of sand-dwelling species, among them the large Oreasterids *Pentaceraster regulus* and *P. multispinus* (Marsh and Rowe, 1978). The islands are largely grass covered with a few shrubs, the largest being *Messerschmidia argentea*. Twenty-two species of plants have been recorded, including seven species of grasses (Hicks 1983).

**Scientific Importance and Research** Ashmore Reef was the principle Sahul Shelf site for a sea snake study during the "Alpha Helix" Expedition, 1972-73 (Dunson, 1975). It was one of two reefs off the north-west coast visited by the "Professor Bogorov" Expedition, 1978 (Anon., 1978a and b) and has recently been surveyed by the Western Australian Museum (Berry *in litt.*, 4.11.86).

**Economic Value and Social Benefits** There is considerable traditional fishing by Indonesians who visit the reef between April and November each year (Forbes, 1982). Invertebrates collected from the reefs include beche-de-mer, clam and *Trochus*, 365 kg of beche-de-mer, 2940 kg of clam meat and 990 kg of fish. The reef is too remote from Australian ports to have much potential for tourism and recreation.

**Disturbance or Deficiencies** The Indonesian fishermen have some impact on the fauna and flora (Hicks, 1983). Seabirds, Brown Boobies *Sula leucogaster*, Lesser Frigatebirds *Fregata ariel*, Common Noddies and Sooty Terns are killed for food, sometimes in large numbers, e.g. in 1981, 100-1500 birds were reported to have been killed on Middle Island. Eggs of birds and turtles are also taken. Turtles (species not recorded) are frequently killed, e.g. in 1974 50 dead turtles were reported. Dugongs are occasionally killed (Hicks, 1983). Sarti (1983) reports that *Trochus* is now scarce. Indonesians have been reported to use explosives (Hicks, 1983).

The Jabiru oil exploration well, which spilled more than 17 000 barrels of oil in a two-day period, is situated adjacent to the Territory of Ashmore and Cartier Islands (The West Australian, October 15, 1983).

**Legal Protection** The Ashmore Reef National Nature Reserve was proclaimed in 1983 (Commonwealth of Australia Gazette, G32, 1983) to "protect the marine and terrestrial environments (of Ashmore Reef) and the wildlife dependent on them, including Sooty Terns and Common Noddies, turtles and a variety of sea snakes. The rights of Indonesian fishermen who traditionally use the area are maintained in accordance with the provisions of the 1974 Memorandum of Understanding (MOU) between Australia and Indonesia" (News Release, Minister for Home Affairs and Environment, Canberra, No. 33 of 1983). This allows Indonesians fishing access and landing on the two smaller islands for the purpose of freshwater collection (Anon., 1986).

**Management** The Australian National Parks and Wildlife Service, P.O. Box 636, Canberra City, S.C.T. 2601, Australia. There were 74 reported violations of the MOU in 1984-85, and numerous patrols to deal with these problems are carried out (Anon., 1986).

**Recommendations** A thorough survey of the reef and its marine resources is required for effective management.

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## BARROW ISLAND RESERVE AND ADJACENT REEFS

**Geographical Location** 56 km off the Pilbara coast, between Port Hedland and Onslow in the Indian Ocean; 88 km north-north-east of Onslow, the nearest port; includes the adjacent Middle, Boodie, and Pascoe and Double Islands; 20°40'-20°58.5'S, 115°18'-115°30'E;

**Area, Depth, Altitude** About 29 m above sea level (Butler, 1982). Off the west coast a depth of 25 m is charted 1.8 km from the coast and the 30 m contour lies about 3 km offshore (Chart AUS 742). The 100 fathom (283 m) line lies approximately 60 km west of Barrow Island (Chart AUS 328)(*see below* for other dimensions).

**Land Tenure** Leased to West Australian Petroleum Pty Ltd (Wapet); under the Petroleum Act the island is crown land for use by one company only.

**Physical Features** Barrow Island is composed predominantly of fossiliferous Miocene limestones which form sea cliffs around much of the island. Coastal exposures of the Miocene extend from Cape Malouet to Eagle's Nest on the western side of the island and from Ant Point to Stokes Point on the east. The northern and southern coasts are covered by Pleistocene deposits and Holocene dunes (McNamara and Kendrick, 1983). The limestones which form the bulk of the island are deeply eroded by occasionally fast flowing streams forming a rugged terrain.

The climate is arid tropical with an average rainfall of 200 mm a year. More than the average may fall in one cyclone or several years may elapse with no rain. A small spring near the mouth of Biggada creek is the only permanent surface freshwater but claypans at the northern and southern ends of the island sometimes hold water for several months after heavy rain. Summer air temperatures over 40°C are common but in winter the daily maximum is about 26°C. Cyclones may occur between November and April. Winds, except when there are cyclones, tend to be easterly during the day changing to south-westerly and westerly at night (Butler, 1982). The western side of the island, including the coral reef is exposed to oceanic swell, the height of which depends, during winter, on southern low pressure systems and, in summer, on tropical cyclones.

No figures are available for sea temperatures but the range is likely to be similar to that in the Dampier

Archipelago but perhaps less extreme (WPD, 1979). The western side of Barrow Island has fairly clear water but clarity decreases during spring tides and with strong wave action. Tidal range is ca. 0.5 m at neaps and ca. 3.5 m at springs.

A fringing reef, enclosing a small clear lagoon, lies on the west side of the island between Turtle Bay and Flacourt Bay, and has an area of about 6.3 sq. km. Other coastal reefs around Barrow Island are algal covered limestone shore platforms with negligible amounts of coral. The shore platforms and coral reef are exposed at low water spring tides. Off the east and south coasts are extensive shoals of less than 5 m depth separated from shoals surrounding the Lowendal and Montebello Islands by a channel 10-16 m deep.

**Reef Structure and Corals** The south-western edge of the reef is emergent at low water springs while the northern end is deeper with areas of isolated coral heads. The landward end of the reef, off Turtle Bay, is sandy with Alcyonacea, sponges and some hard corals while the outer reef flat has a dense cover of living coral. There are no detailed studies on the structure or zonation of the reef.

Limited collections of reef corals have been made at low tide only and are unlikely to fully represent the coral fauna of Barrow Island. About 24 species in 15 genera have been collected, most of them from Turtle Bay. These comprise:

*Pocillopora* (1-2 spp.)
*Acropora* (5 spp.)
*Montipora* (2 spp.)
*Porites* (1-2 spp.)
*Cyphastrea* (1 sp.)
*Favia* (1 sp.)
*Favites* (2-3 spp.)
*Goniastrea* (2 spp.)
*Leptoria* (1 sp.)
*Plesiastrea* (1 sp.)
*Echinopora* (1 sp.)
*Trachyphyllia* (1 sp.)
*Culicia* (1 sp.)
*Euphyllia* (1 sp.)
*Turbinaria* (1 sp.)

and the Hydrozoan coral *Millepora* sp. This fauna may be compared with 66 species in 30 genera from the Monte Bello Islands (limited collecting) or 100+ species in 53 genera from the Dampier Archipelago (fairly thorough collecting from diverse habitats).

**Noteworthy Fauna and Flora** Little is known of the marine fauna and flora of Barrow Island. Seven marine mammals including Dugong *Dugong dugon* have been recorded from the island. The island is an important Green Turtle *Chelonia mydas* nesting site, particularly at Turtle Bay and Middle Island. Loggerhead Turtles *Caretta caretta* also occur at Barrow Island (Limpus, 1981). The echinoderm fauna is a mixture of Indo-West Pacific coral reef species and north-west Australian inshore species. Fifty-seven species have been found of which only 13 were from the coral reef. The only species of note, so far recorded, is a new species of heart urchin, *Rhynobrissus tumulus* (McNamara, 1982) from the north end of Barrow Island.

The island is regarded as a sanctuary of worldwide significance (EPA, 1975). It supports 16 species of land mammals, including eight species of marsupials most of which are rare or extinct elsewhere. There are 105 bird species, including one found only on one other island, 48 reptiles and one frog species (Butler, 1982).

**Scientific Importance and Research** No research has been carried out on the Barrow Island coral reef.

**Economic Value and Social Benefits** The production and maintenance workforce of the Barrow Island oilfield work a nine-hour day and are obliged to spend their recreational leave away from the island to reduce their impact on the environment. However, there is some island recreation including fishing by line and spear, and shell collecting. Spear-fishermen from Pilbara coastal towns operate from boats around Barrow Island.

**Disturbance or Deficiencies** Barrow Island has an oilfield, covering nearly half the island, with 362 wells currently producing about 8.7 million barrels of oil a year. A submarine pipeline, on the east side of the island, carries oil to a marine terminal 10 km offshore (Butler, 1982). Through strict environmental safeguards the coastline and reef have remained unpolluted but there is the ever present possibility of a major oil spill. The impact of spearfishing is not known.

**Legal Protection** Barrow Island was given Nature Reserve status in 1910. It is now designated "A" Class Reserve A11648, reserved for the protection of flora and fauna (land to low water) and is vested in the Western Australian National Parks and Nature Conservation Authority. All company and contractor workforce and visitors are required to formally accept the strict environmental measures maintained by Wapet on Barrow Island. The sale of shells, use of boats around the island and spearfishing in Turtle Bay are prohibited. Persons other than company employees, contractors and official visitors are not permitted on the island.

**Management** It is managed by West Australian Petroleum Pty Ltd, 233 Adelaide Terrace, Perth, Western Australia 6000 with the assistance of a Conservation Consultant, working in collaboration with the Western Australian Department of Conservation and Land Management, P.O. Box 104, Como, W.A. 6152.

**Recommendations** A detailed study of the Barrow Island coral reef should be made to determine its significance. It is believed to be representative of the inshore coral reefs of the Pilbara coast. Under the present management regime it is already afforded more protection than any other reef in the area and this should be ensured for the future.

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## CHRISTMAS ISLAND AND ADJACENT REEFS

**Geographical Location** Eastern Indian Ocean about 290 km south of the Indonesian island of Java and 850 km north-east of the Cocos-Keeling Islands; 10°35'S, 105°35'E.

**Area, Depth, Altitude** Island area approximately 13 700 ha surrounded by narrow, steeply-sloped, fringing reef with active coral formation to depths of about 20-30 m. The maximum elevation of the island is 381 m.

**Land Tenure** Commonwealth Government of Australia with mining lease held by the British Phosphate Commission.

**Physical Features** Christmas Island is a moderately high, volcanic island capped with limestone and extensive guano deposits and is described by Gray (1981). The coastline is extremely irregular, consisting mainly of sheer rocky cliffs which average 10-20 m in height. There are about a dozen small beaches, most under 30 m in length, which are usually exposed only at low tide. There is an average tidal fluctuation of about 1.5-2 m, but due to the precipitous nature of the shore, a well-developed intertidal zone is largely absent, except at Ethel and Lilly Beaches on the north-east coast. There is an extensive elevated terrace, approximately 3-4 m wide, perched about 2-3 m above mean sea level at North West Point which contains a number of large splash pools with depths of 0.2-1 m. The surrounding waters are remarkably clear and support a rich fringing coral reef, which extends for about 20-200 m seaward before plunging steeply to deep water. Inland, the island rises steeply with an initial series of coastal terraces, forming a scenic backdrop of cliffs, some rising 100-175 m. Most of the interior plateau consists of relatively gentle sloping hills which are heavily forested except where there are mining activities. The climate is tropical with an average annual rainfall of about 2000 mm.

**Reef Structure and Corals** Mainly a narrow limestone platform extending out from shore for 20-200 m and gradually sloping to a depth of 5-20 m before dropping steeply (nearly vertical in some places) for several hundred metres. There is very little reef diversity, with the near shore platform and outer slope being dominant structures. The seaward edge of the shallow platform supports a rich diversity of hard and soft corals which gradually disappear on the outer slope with increasing depth. Black coral (Antipatharia), gorgonians (Gorgonacea), and sponges (Porifera) are prominent on the steeper sections of the outer slope between about 15 and 70 m.

**Noteworthy Fauna and Flora** Most notable are seabirds, terrestrial crabs, marine invertebrates, and fishes. A number of seabirds nest on the island, including several endemic species or subspecies: Christmas Island Frigatebird *Fregata andrewsi*, Golden Bosun *Phaethon lepturus fulvus*, and Abbott's Booby *Sula abbotti*. About 16 species of crabs are known from intertidal and terrestrial habitats (Hicks *et al.*, 1984), of which the endemic Red Crab *Gecarcoidea natalis* is perhaps the most noteworthy. They live in forested inland areas feeding mainly on fallen leaves, fruits and flowers. At the onset of the rainy season (about November) incredible numbers (in virtual plague proportions) migrate to the sea in order to breed. The Coconut or Robber Crab *Birgus latro* is another common terrestrial species. Marine fish and invertebrates display a greater affinity with the Pacific Ocean fauna than those typical of the Indian Ocean. They are typical of other Indo-Pacific coral reef areas, but because of the absence or scarcity of certain habitats such as protected lagoons, intertidal zone, and mangrove estuaries, diversity is relatively low. The fish are described by Allen and Steene (1979).

**Scientific Importance and Research** Christmas Island has been the focus of considerable research beginning with C.W. Andrews of the British Museum (Natural History), who visited in 1897-98 and in 1908. Major biological investigations were conducted between 1938 and 1940 under the direction of C.A. Gibson-Hill of the Raffles Museum, Singapore and crabs, echinoderms, insects, reptiles, birds and mammals were collected. More recently, scientists from the Western Australian Museum have made four separate visits to the island. E.J. Car and G.F. Mees collected marine invertebrates and fish in 1961; in 1969, S.M. Slack-Smith and G. Paterson of the Museum's Mollusc Department collected approximately 85 species of molluscs and about 20 species of echinoderms; and in 1978 G.R. Allen and R.C. Steene collected fish, bringing the species total to 484 (Allen and Steene, 1979) and R.W. George surveyed land and freshwater crabs. The island is particularly well suited for future investigations of fish and invertebrate communities on the steep outer reef slope which is perhaps the most poorly documented of the reef's major zones, primarily because of logistic problems associated with deep diving. However, because of its proximity to the shore and sheltered conditions which usually prevail on the north shore, this zone is highly accessible, particularly adjacent to the Cantilever loading dock in Flying Fish Cove or under large shipping buoys moored in the cove.

**Economic Value and Social Benefits** The island is currently inhabited by about 3 000 Asians and 300 Europeans who are involved with phosphate mining operations. Visitors are largely made up of friends and relatives of island residents and tourism is not promoted. When mining is no longer economically feasible, the island will have great potential as a tourist destination.

**Disturbance or Deficiencies** Coral cover on the upper terrace was greatly reduced during the 1982/83 El Niño. Disturbance to the marine environment appears to be highly localized and is primarily confined to Flying Fish Cove, the island's only anchorage and the site of the phosphate loading dock. Reef has been damaged adjacent to the Cantilever dock, but it is minimal if the island's entire coastline is considered. There is also sewerage discharge into the Cove and constant spillage of phosphate during the loading process, but no deleterious effects are apparent. If hotels are eventually constructed and the tourist trade is catered for, there will be a need for control of shell and coral collecting, and possibly fishing.

**Legal Protection** In 1980, Christmas Island National Park was established in the Egeria Point area (south-west corner of the island), covering 1600 ha or about 12% of the island's area. It includes shore terraces with coastal cliff escarpments, the island's only waterfall, and an undisturbed section of rainforest (IUCN, in prep.). There is no reef protection.

**Management** A government conservator was appointed to the island in 1977. Appropriate measures have been taken to afford legal protection to the island's wildlife, control importation of exotic fauna and instil conservation values through education programmes. Address: Wildlife Conservator, Territory of Christmas

Island, Government Offices, Christmas Island, Indian Ocean. National Park Administration: Director, Australian National Parks and Wildlife Service, PO Box 636, Canberra, A.C.T. 2601, Australia.

**Recommendations** While steps have been taken to conserve the terrestrial biota, the marine flora and fauna has been largely ignored. It seems desirable to set aside all or most of Christmas Island's surrounding reef as a nature reserve, but surveys are required to determine the degree of protection that might be warranted.

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## COCOS-KEELING ISLANDS

**Geographical Location** south-east Indian Ocean, about 900 km from the Sunda Straits and Christmas Island; 12°S, 96°56'E.

**Area, Depth, Altitude** Total area about 200 sq. km; max. alt. about 8 m.

**Land Tenure** Protectorate of Australian Commonwealth Government; coconut plantations and much associated land was originally owned by Clunies-Ross Estate until 1984 when it was resumed by the Government.

**Physical Features** The Cocos-Keeling islands are a small isolated group composed of an atoll with 25 islands, and a single island named Keeling about 24 km to the north which was also described as an atoll by Darwin (1842). The southern atoll is approximately 11 x 15 km and has a lagoon which is mainly shallow (only 1-3 m in the south) and reaches a maximum depth of about 20 m. The outer slopes decend at an average angle of 45° to at least 1 km deep. It is joined to Keeling Island by a submerged ridge 900 m deep. Keeling is oval and approximately 1 x 2 km in size. In the east there is a pass into a central, small lagoon which is extremely shallow.

The islands lie within the influence of the south-east trade winds which are fairly steady, with infrequent cyclones. Rainfall averages about 2000 mm a year, with most falling in from February to July (Stoddart, 1971). The spring tidal range is about 1 m, and with wave action on the outer reefs this is sufficient to maintain good water exchange and coral growth in the lagoon. The principal current affecting the islands is the South Equatorial Current which circulates anti-clockwise. Occasionally wind-driven currents develop, bringing surface water and associated flotsam, including pumice and possibly larvae, from the Java-Indonesia region instead of from Australia.

**Reef Structure and Corals** In the southern atoll, much of the southern part of the lagoon resembles a deep reef flat with rich growths of *Acropora*, seagrass *Thalassia* and the algae *Caulerpa* and *Halimeda*, but has deep, sometimes interconnected, pools into it (Maes, 1967). The shallowest parts have calcareous mud flats which are poor in life, but support some molluscs and crabs. The northern part of the lagoon has greater water exchange, and patches of hard and soft corals are common on the soft substrate, particularly *Porites*; there is a vertical relief of about 2-3 m over 100 sq. m.

The reef flat is more or less continuous around the entire atoll apart from two passes, 10 m deep or less, adjacent to Horsburgh Island in the north and is edged with a crest, although broad gaps exist between West Island and Turk Reef, to the east of Turk Reef and west of Direction Island. Between the reef crest and the islands, the reef flat is mostly very shallow or emerged at low tide; illustrations in Gibson Hill (1950) show a substantial coral cover on the exposed parts.

To seaward of the reef crest, the bottom generally slopes gradually to about 10-15 m, then plunges steeply to well over 60 m. A spur structure exists around much of the atoll, with buttresses dropping to 28 m or more. The grooves between the spurs contain sand, rubble and large boulders. The reef slope below the buttresses is characterized by rubble and has only a little live coral. No data are available on the coral formations of Keeling Island.

Wells (1950) reported a poor coral fauna of 74 species from Cocos-Keeling. Notable absences include the genera *Stylophora, Euphyllia, Goniopora, Platygyra, Goniastrea, Merulina, Turbinaria, Galaxea* and all genera of the Mussidae and Pectinidae. Of the corals identified by Wells (1950) from a much earlier collection, 12% were Indian Ocean compared to 35% of apparent Pacific origins. No survey of the reef slopes has been done and other species may be found there. Colin (1977) does not describe corals. Other taxa were also found to be relatively sparse, and lack of recruitment in this isolated atoll is presumed to contribute to the high proportion of unoccupied substrate.

**Noteworthy Fauna and Flora** Horsburgh Island has large bird populations, for a reason related by Gibson Hill (1950). It was the home of girls aged 15 and 16 who were sent to live there to tend vegetables "to prevent them succumbing to their natural inclinations at too young an age...." No-one was allowed to land on the island without a special permit. The birds on the island were therefore never hunted and are found here in greater abundance than on other islands.

**Scientific Importance and Research** Charles Darwin was the most notable of the early naturalists who visited the islands. Cocos-Keeling was the only atoll on which he landed, but he wrote that by that stage he had already formulated the fundamentals of his theory of atoll formation. Forbes (1885), Guppy (1889) and Wood-Jones (1909) also provide useful information on the islands and detailed descriptions are given by Gibson Hill (1950) who was resident on the islands as medical officer in 1940-41. Volume 22 of the Bulletin of the Raffles Museum is devoted to his observations and to lists of species collected by him.

In 1974 the Academy of Natural Sciences in Philadelphia carried out an ichthyological collecting trip in the course of which Colin (1977) carried out a brief sublittoral examination of the reefs, earlier studies having been principally by foot on the reef flats and in the shallows only. Molluscs remain the best studied marine taxonomic group (Maes, 1967) and this study provided valuable zoogeographic information, showing the atoll as an outpost of the Pacific Ocean, situated well inside the Indian Ocean. Although Australia lies upcurrent in the South Equatorial Current, Maes (1967) found no exclusively Australian mollusc species in his survey.

Cocos-Keeling therefore appears to be an extension of the Indonesian region, rather than of the Australian region, as several molluscs are found also in Java and Sumatra. Only 2.5% of the molluscs found were Indian Ocean endemic species, while 15% were of restricted Pacific Ocean distribution (the remainder being pan-tropical). Similar ratios appear to apply to the fish and coral faunas (*see above*). Thus, Maes (1967) concludes that the fauna of the Cocos-Keeling reefs has a more strongly Pacific than Indian Ocean character. The distant location of the atoll from other land, and the directions of the prevailing current have been invoked as causes.

**Economic Value and Social Benefits** The islands were discovered in the early 17th Century, and have been inhabited since 1826, since when they have been intensively farmed for copra.

**Disturbance or Deficiencies** The islands have minimal human interference of the kind likely to threaten the reefs although damage has been caused by storms and the area is affected by occasional, small earthquakes. An earthquake in 1876 apparently caused the release of a black, sulphorous liquid into the lagoon killing all the corals and fish in the southern, enclosed part (Colin, 1977). Colin (1977) recorded the presence of fairly large numbers of *Acanthaster planci* and there was evidence of much greater coral cover prior to his visit. He attributed the decline to infestation by the starfish. Occasional patches of abundant coral were found which had not been affected. Red tide phenomena have been reported. The bird fauna on North Keeling Island is threatened by local fishermen who collect Great Frigatebirds *Fregata minor minor*, Red-footed Boobies *Sula sula*, terns (Laridae) and tropicbirds *Phaethon* spp. for food. The endangered Cocos Buff-banded Rail *Rallus philippensis andrewsi* is threatened by hunting (Anon., 1985b). There is little natural top soil and much has been imported, along with numerous soil faunal species.

**Legal Protection** None.

**Management** The islands are managed by the Australian Department of Territories, Canberra, A.C.T.

**Recommendations** Too little is known about the coral reefs of Cocos-Keeling to make firm recommendations at this time. Its position as an outlyer of Pacific fauna in the Indian Ocean suggests that there is inherent value in preserving at least representative reef habitats, but surveys are required to determine the degree of protection that might be warranted. With the effective return of day-to-day control of marine resources to the indigenous people, it is likely that demands on the marine environment will increase and diversify. Marine surveys and scientific advice will help the people to conserve and develop their marine resources to the best advantage.

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## DAMPIER ARCHIPELAGO RESERVES AND RECOMMENDED MARINE RESERVES

**Geographical Location** From Cape Preston to Point Sampson, eastern Indian Ocean, approximately 1600 km north of Perth, in the Pilbara region (Pilbaraland); 20°20'-20°50'S, 116°20'-117°10'E.

**Area, Depth, Altitude** The archipelago consists of ten large (greater than 3 km long) islands: Legendre, Angel, East Lewis, West Lewis, Conzinc, Rosemary, Enderby, Delambre, Kendrew and Dolphin Islands, and numerous small islands covering an area of approximately 4000 sq. km. They lie within the 20 m isobath; max. alt. (West Lewis Island) approx. 120 m.

**Land Tenure** Western Australian Government.

**Physical Features** The Dampier Archipelago is an inundated landmass similar in topography to the present hinterland. Much of the coastline is igneous rock of Archean age. The geology of the archipelago consists of post-Archean intrusive granophyre, gabbro and dolerites (Gidley granophyre) and Archean metasedimentary and metavolcanic rocks (Semeniuk *et al.*, 1982).

The climate of the Pilbara region is tropical and arid (Gentilli, 1972). Annual average rainfall and evaporation are approximately 300 mm and 3500 mm respectively. The area is subject to periodic cyclones during December to April; Coleman (1971) shows that a cyclone passes within 100 km of the coast every 2-3 years. The outer areas of the archipelago are subject to long period wave activity during winter (June to August) from temperate low pressure systems and from tropical low pressure systems during summer (December to April). Tides are semi-diurnal with a maximum spring range of approximately 4.9 m. Two broad hydrographic zones exist in the Dampier Archipelago: (1) the outer exposed seaward zone and (2) the inner protected zone. The outer seaward zone has surface seawater temperatures of 21-31°C, surface salinity of 35-36 ppt and maximum current speeds of 60 cm/sec. The inner zone has sea temperatures of 19-33°C, surface salinities of 35-37 ppt and maximum current speeds of 30 cm/sec.

Barrier reefs, Hamersley Shoal and Sailfish Reef, on the seaward edge of the archipelago are exposed to constant wave action. A few fringing reefs adjacent to islands and rocky coasts (Legendre Island, Angel Island) are found in the outer areas of the archipelago exposed to intermittent wave action. Small patch reefs are located in the sheltered inner areas near islands and rocky coasts.

**Reef Structure and Corals** Habitats in the Dampier Archipelago range from those exposed to high wave energy, clear water and low sediment deposition rates (the seaward reefs of Delambre, Legendre, Rosemary and Kendrew Islands) to extremely sheltered areas with turbid water and high sediment deposition rates (Withnell Bay). Many intermediate situations exist with shores of different aspect, topography and slope and with varying current patterns. The rich coral fauna (55 genera, 144 species of symbiotic corals; 2 genera and 4 species of non-symbiotic corals) plus the hydrozoan genus *Millipora* (Marsh, pers. comm.) in this region is indicative of the high habitat diversity. Certain species (*Pocillopora eydouxi, Pavona minuta*) only occur on the seaward reefs while others (*Montipora erythraea*) only occur in lagoonal situations. Some species (Fungiids) are only found on sand while others (*Duncanopsammia, Caulastrea, Trachyphyllia, Moseleya* and *Euphyllia*) occur only in turbid inshore situations. Other species vary in their abundance under different conditions, i.e. *Turbinaria frondens*, characteristic of the inshore waters, is present, but rare on the seaward reefs and *Acropora hyacinthus*, abundant on seaward reefs, is uncommonly found at the inshore sites (Marsh, 1978).

The coral species on the outer seaward reefs are predominantly tabular acroporids (mainly *A. hyacinthus*) and to a lesser degree pocilloporids (*P. damicornis*). Live coral cover varies from greater than 60% (Hamersley Shoal) to less than 10% (Sailfish Reef).

**Noteworthy Fauna and Flora** The Dampier Archipelago is a major turtle nesting area (Morris, pers. comm.). The Green Turtle *Chelonia mydas* is common; the Flatback *Chelonia depressa*, the Hawksbill *Eretmochelys imbricata*, and the Loggerhead *Caretta caretta* breed from October to March. Dugongs *Dugong dugon* occur (June to September) but are uncommon. Humpback Whales *Megaptera novaengliae* have been observed during July to September usually moving south and often with calves. The following reef fish are heavily fished by line and spear by recreational fishermen: coral trout *Plectropomus* sp., tusk fish *Choerodon* sp. and rock cod *Cephalopholis* sp. Beyond the outer seaward reefs, marlin *Makaira* sp., sailfish *Istiophorus* sp., spanish mackerel *Scomberomorus* sp., golden travelly *Gnathanodon* sp. and turrum *Caranx* sp. are popular game fish. The Green Crayfish *Panuliris versicolor* is common and is taken by divers. The Painted Crayfish *P. ornatus* is relatively rare. The Dampier Archipelago is an important nesting site in Western Australia for the pelican *Pelicanus conspicillatus*.

*Sargassum* sp. is a predominant alga; the calcareous green alga *Halimeda* sp. and seagrass *Halophila* sp. occur but are not widespread. Widespread "blooms" of the planktonic, blue-green alga *Trichodosmium erythraeum* occur from December to April. There are seven species of mangroves, the predominant species being *Avicennia marina* and *Rhizophora sylosa*. Cyanobacterial mats (*Microcoleus* sp.; *Phormidium* sp.) occur in the intertidal salt flats landward of the mangroves.

**Scientific Importance and Research** The coral reefs in the Dampier Archipelago are the only reefs in Australia found in a tropical, arid setting that have research facilities nearby and, as such, enable comparisons with tropical, non-arid coral reefs to be made. The Western Australian Department of Conservation and Environment is conducting a multi-disciplinary study in this area including research on water movement, heavy metals in the water and biota, sediment dynamics and mineralogy, ecology of corals, macroalgae, epilithic algae (algal turf), mangroves, cyanobacterial mats and nearshore fish populations. The Western Australian Museum has conducted surveys on corals and associated invertebrate fauna, molluscs, fish, and the ecology of the Crown-of-Thorns Starfish *Acanthaster planci*. The Western Australian Department of Conservation and Environment maintains a research facility, with laboratory and accommodation facilities for 6-8 personnel, in the township of Dampier.

**Economic Value and Social Benefits** The coral reefs in the Dampier Archipelago are used extensively by recreational line and spear fishermen. A pearling lease is current for the collection of pearl shells in the archipelago and mining tenements exist for some of the beaches for lime sand mining.

**Disturbance or Deficiencies** Dredging for shipping access in the inner areas of Mermaid Sound and the subsequent dumping of dredge spoil represent the greatest threat to reefs in this area. The pressure of recreational fishing on fish and crustacean populations is unknown but is considered to be high. The impact of amateur and professional shell collectors and the effect of increasing recreational use of the beaches on turtle nesting is unknown.

**Legal Protection** The islands to low water mark are classified as C class reserves (#15 C36913, C36915) vested in the Western Australian National Parks and Nature Conservation Authority. This classification is essentially for recreation, and provides little protection to flora and fauna on the islands and none to the marine flora and fauna.

**Management** The Western Australian Department of Conservation and Land Management (P.O. Box 104, Como, W.A. 6152) is the authority responsible for the area.

**Recommendations** At the conclusion of the Dampier Archipelago Marine Study, guidelines for the management of the marine resources in this area will be drawn up by the Western Australian Department of Conservation and Land Management. Legislation should be provided to ensure that areas of particular biological significance are protected and perhaps declared marine reserves. For example, Conzinc Island has an extremely diverse and abundant coral and fish fauna and the intertidal area on the southern side of Legendre Island supports large numbers of turtles and seabirds.

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## HOUTMAN ABROLHOS ISLANDS RESERVES AND PROPOSED MARINE RESERVES

**Geographical Location** East Indian Ocean, 80 km west of Geraldton, and 10 km east of the shelf edge (200 m contour) (Charts: Royal Aust. Navy Hydrographic Service, AUS 332 and AUS 333); 28°15'-29°00'S, 113°30'-114°05'E.

**Area, Depth, Altitude** The islands cover an area of approximately 18.5 sq. km, and the associated reefs an area of 1104 sq. km to the 50 m contour line. Maximum altitude is ca. 50 m above sea level.

**Land Tenure** Western Australian Government: islands and surrounding seabed to the 3 n. mile (5.6 km) limit; Commonwealth Government: seabed to the 12 n. mile (22.2 km) limit and control of access to resources to the 200 n. mile (370.6 km) limit.

**Physical Features** The islands and their associated reefs comprise three groups: the Pelsaert (Pelsart) Group (including Pelsaert and Gun Islands), the Easter (or Middle) Group (including Rat and Wooded Islands), and the Wallabi Group, including Beacon Island, East and West Wallabi Islands, and North Island. The Zeewyck

Channel to the south, and Middle Channel to the north define the groups. The archipelago is separated from the mainland by the Geelvink Channel (Wikham and Stokes, 1840) The reef complexes are compound continental shelf atolls consisting of a karstic, Pleistocene coralline limestone basement supporting a veneer of Holocene growth (Fairbridge, 1947 and 1950). The islands are of the same Pleistocene reef core, with aggregated coral rubble, sand and aeoleonite facies. The upper surface of the limestone core has been eroded to a relatively uniform height of 2-3 m above sea level, and is strongly undercut in the intertidal zone. The larger islands (e.g. East and West Wallabi) have well developed dune structures overlying dune limestones and shell and coral limestones (Teichert, 1947).

There are a total of at least 100 islands ranging from intertidal sand or rubble cays of a few hundred sq. m (e.g.: Disappearing Island), to vegetated dune-covered limestone islands 6 sq. km rising to 50 m above sea level. The reefs consist of emergent perimeter and platform reefs defining lagoons which range in mean depth from 6 to 25 m. The windward reef slopes shelve in a series of terraces to the shelf break (200 m) located 5-12 km west of the reef crest. The leeward reef slopes drop steeply to the surrounding shelf depth of 40-45 m in inter-group channels and east of the leeward margins (RAN Hydrographic Sheets # 1639-1642, 1974).

The location of the reefs at the edge of the continental shelf places them under the influence of a unique, south-flowing eastern margin oceanic current (the Leeuwin Current) which flows from the tropics along the outer edge of the central and southern continental shelf of Western Australia (Cresswell and Golding, 1980). The current is best defined from about February to October (late summer to spring) (Golding, 1980; Hatcher and Walker, 1984), with the result that sea temperatures surrounding the Abrolhos are substantially (2.5-7.0°C) higher than those near the coast at similar latitudes during the cold season (Rochford, 1984). The annual range of mean seawater temperature at the Abrolhos is 20-24.7°C with an absolute range of 18.6-26.3°C (Hatcher *et al.*, in press). Within the lagoons the absolute range is 17.2-28.6°C due to evaporative cooling and radiant heating (Crossland, 1981 and 1984; Hatcher, unpub. data). The Leeuwin current is thus implicated as a primary factor contributing to the development and continued existence of the Abrolhos Reefs (Johannes *et al.*, 1983a; Saville-Kent, 1897).

The tidal regime is mixed semi-diurnal/diurnal, with an annual mean amplitude of 0.35 m and a spring-neap range of 0.4-1.2 m (Hatcher and Godfrey, unpub. data). Tidal currents on the surrounding shelf are weak (Steedman *et al.*, 1977), but can be strong near the reefs. The occasional co-occurence of barotropic tides and daytime low spring tides, with calm seas in summer, can result in sporadic, prolonged emergence of intertidal reef flats and lagoon patch reef tops (Dakin, 1919; Hatcher, pers. obs.).

The weather pattern is moderately predictable, being controlled by the north-south movement of the subtropical anticyclonic wind belt, and an eastward progression of high pressure cells. The prevailing winds in summer (December to February.) are strong SE-SW, with short periods of calm. At this time tropical cyclones are common in areas to the north and cause strong winds and high seas at the Abrolhos, but very rarely of cyclonic intensity near the reefs (Aust. Bur. Met., Tropical Cyclone Record). In winter (June-August) the winds are variable from the SW - NE, and less strong, apart from periodic gales which have a greater frequency in winter than in summer. The other months are transition periods, with the switch to summer southerlies being the most rapid (France, 1987; Hatcher and Walker, 1984; Steedman, 1977).

Rainfall is low (about 450 mm a year) and concentrated in the May-August (winter) period; there is little or no effect from coastal runoff. The prevailing ocean swell is generated by the westerly, circumpolar wind drift. It is thus consistently large and from the south in summer, swinging towards the south-west in winter and increasing in mean amplitude and variability. The significant wave period averages 8-12 sec with a significant height amplitude of 2-3 m. Calm sea conditions occur only 1.5% of the year, primarily in winter (France, 1987; Steedman, 1977; Wedd and Beer, 1978).

**Reef Structure and Corals** The three groups present a sequence of increasingly open atoll-like structures, from a continuous windward ribbon-reef and eastern island-chain perimeter enclosing all but the northern end of the Pelsaert Group, to a series of island groups on broad reef platforms intersected by moderately deep channels in the Wallabi Group. The enclosed lagoons are of variable structure. They range from shallow, patch-reef studded forms behind windward reef margins which receive large inputs of reef-generated sediment, to deep basins defined and dissected by steep walls of karstic origin. The Pelsaert and Easter Groups have extensive fields of drowned dolines (blue holes) in the eastern and north-eastern sections of the lagoons, while West Wallabi and North Island are surrounded by tidal flats on all sides, with fringing reefs on the western sides (Teichert, 1947).

Most reef structural types are represented, but several of these are relict structures of Pleistocene origin, while others are the result of recent growth (Teichert, 1947). The windward reef slopes (south to west exposure) exhibit spur-and-groove topography and wave cut terraces at at least two depths. They are virtually devoid of living coral (cover less than 1%, low branching and encrusting forms in isolated colonies), and support extensive stands of macroalgae (including kelp) to depths of at least 40 m. A bank with a depth of 20 m parallels the western reef margin about 1.5-3 km off the crest. A second bank at 10 m is located 0.5-1 km out and breaks continuously in all but the calmest weather (Hatcher, pers. obs.). In contrast, the leeward (east to north exposure) reef slopes and those facing the deep inter-reef channels drop steeply to the average shelf depth of about 40 m, and support an extensive and diverse coral community (cover 40-95%), including tabular and branching *Acropora* spp., foliose *Montipora* spp., and *Pachyseris* spp. (Wilson *et al.*, 1977).

Reef flats vary greatly in structure depending on the degree of exposure. Windward reef crests receive consistant swell and are emergent, low relief, heavily cemented pavements of Pleistocene limestone rock strewn with large boulders. They are algal dominated, with few scattered colonies of low growing coral forms (Wilson *et al.*, 1977). The algae seasonally form polygonal patterns of macrophytic brown algal borders surrounding low turf algal communities. The abundance of macroalgae and coral colonies increases on the back reef as a function of distance from the reef crest (Rimmer, in prep. a). Leeward reef flats are rarely emergent and consist mainly of unconsolidated coral rubble. Submerged reef platforms form extensive flats surrounding many of the islands. They consist of a relatively smooth limestone surface covered with unconsolidated material and colonized primarily by fucoid algae (mainly *Sargassum* spp.). There is a low cover of coral (5-20%), principally massive species such as *Goniastrea* and *Lobophyllia* spp.) except at the perimeters and around the deep holes where coral abundance increases markedly (up to 90% cover, mainly branching *Acropora* spp.) (Wilson *et al.*, 1977). These lagoonal platforms are often so pock-marked with circular holes as to take on the appearance of a maze.

Lagoon patch reefs are usually submerged to a depth of 1-2 m, and the upper 4 m are dominated by macroalgae on a poorly consolidated substratum. Dense stands of branching and tabular *Acropora* spp. characterize the sides of these reefs to a depth of about 10 m. In deeper water and channels this community gives way to a high diversity coral community including several massive forms (20-60% cover) (Wilson *et al.*, 1977).

The coral diversity at the Abrolhos is very high for a reef at this latitude. There are approximately 136 species of hermatypic corals in 40 genera, plus a further 10 species of ahermatypes in eight genera. All but two coral species are tropical. The ca. 40 species of *Acropora* dominate both shallow leeward and lagoon patch reef habitats. At deeper and/or more sheltered sites genera including *Montipora, Echinophyllia, Oxypora, Mycedium, Pachyseris* and *Leptoseris* are common. Species of *Porites, Pocillopora*, and *Pavona* can be found in more exposed habitats, but many of the forms adapted to high energy hydrodynamic regimes are lacking at the Abrolhos. No *Millepora* or *Heliopora*, and few fungiids have been recorded from the reefs (Hatcher and Walker, 1984; Thorpe, 1928; Veron, 1985; Veron and Marsh, unpub. data; Wilson and Marsh, 1979).

**Noteworthy Fauna and Flora** The Abrolhos occur in a zone of overlap between the Dampierian and Flindersian Biogeographic Provinces, and thus are at or near the extremity of the ranges of many tropical and temperate species (Wilson and Marsh, 1979). Most notable are the tropical corals belonging to the genus *Acropora*, and the temperate kelp *Ecklonia radiata*, which is confined to exposed habitats (Hatcher *et al.*, in press). The other major contributor to benthic biomass is the genus *Sargassum*, of which there are at least six species, showing both tropical and temperate affinities. Algal diversity is very high (more than 100 spp.) of which 25% are tropical and 35% are temperate, while the remainder have affinities with taxa having broad geographic ranges. In contrast to low latitude coral reefs, macroalgae are abundant in most habitats (Hatcher and Rimmer, 1985; Hatcher and Walker, 1984; Rimmer, in prep. a and c; Wilson *et al.*, 1977).

The islands are at the southern end of the geographic range of several molluscan species including the Giant Clam *Tridacna maxima*, the Black-lipped Pearl Shell *Pinctada margaritifera*, and the Geographer Cone *Conus geographus*. A few achaeogastropods are particularly abundant on shallow reefs, e.g.: the tropical trochid *Tectus pyramis*, the Western Australian endemic starshell *Astraea tentoriiformis*, and the temperate turban shell *Turbo intercostalis*, (Hatcher and Rimmer, 1985; Hatcher and Walker, 1984; Wilson *et al.*, 1977). These species are important components in the reef food web (Hatcher, 1985; Hatcher, unpub. data; Walker, 1983). The temperate, Giant Turban Shell *T. jourdani* occurs in high localized abundances on the windward slopes to depths of at least 50 m (Hatcher, pers. obs.).

Of the 142 species of echinoderm recorded, 75% are tropical (several of which do not occur further south), 15% are temperate, and 9% are endemic to the coast of Western Australia (Dakin, 1916; Devaney and Barker, in prep.; Hatcher and Walker, 1984; Marsh, 1976 and in prep.; Marsh and Marshal, 1983). With a few localized exceptions (e.g.: boring echinoids, *Echinometra mathaei* on windward reef crests) echinoderm abundance is low compared to many tropical coral reefs (Hatcher and Rimmer, 1985; Wilson *et al.*, 1977).

The fish fauna is impoverished Indo-West Pacific, with a significant temperate Australian component. Of the 300+ species, 66% are tropical, 26% are temperate, and 8% have undetermined affinities. There are few endemic species. While the best represented families are tropical, the Siganids, Acanthurids, and Scarids are poorly represented (one, three and five spp. respectively) and, with the exception of juvenile Scarids, are never seen in large schools (Allen, in prep.; Hatcher and Walker, 1984; McKay, 1967 and 1970; Mees, 1959, 1960 and 1962; Wilson *et al.*, 1977). This paucity of the major herbivorous fish contrasts sharply with tropical coral reefs. On the other hand, two members of the family Kyphosidae (*K. sydneyanus* and *K. cornelii*) are very abundant in most reef habitats at the Abrolhos, and exert a significant and complex influence on the benthic biota through their herbivorous activities (Hatcher and Rimmer, 1985; Rimmer, 1986; Rimmer and Hatcher, in prep.; Rimmer and Wiebe, in prep.). The smaller reef sharks are curiously absent from the reefs, but numerous large pelagic species are common.

Several species of fish are commercially important, and intensively harvested at the Abrolhos. They include the Bald-chin Grouper *Choerodon rubescens*, the Western Australian Jewfish *Glaucosoma hebraicum*, the Pink Snapper *Chysophrys auratus* and the Coral Trout *Plectropomus maculatus* as well as two shellfish: the Western Rock Lobster *Panulirus cygnus* (George *et al.*, 1979) and the Saucer scallop *Amusium balloti*.

The Australian Sea Lion *Neophoca cinerea* is common at the Abrolhos, and breeding has been observed. Bottlenose Dolphin *Tursiops* sp. are abundant, and at least three species of whales are regularly sighted around the reefs and in the lagoons during migration seasons. These are the Humpback Whale *Megaptera novaeangliae*, Bryde's Whale *Balaenoptera edeni*, and the Minke Whale *B. acutorostrata* (Hatcher and Walker, 1984). Both the Green Turtle *Chelonia mydas* and the Loggerhead Turtle *Caretta caretta* have been sighted at the Abrolhos. The Green Turtle has been observed to mate but no successful nests have been documented (Hatcher, pers. obs.).

At least 20 species of seabirds breed on the islands (seventeen at Pelsart Island). They include ubiquitous groups such as petrels (including shearwaters), cormorants, herons, gulls, hawks, and eight species of terns but also the White-breasted Sea Eagle *Haliaeetus leucogaster* and the Lesser Noddy Tern *Anous tenuirostris*, which is known to breed at only one other location in the world (Conigrave, 1916; Ealey, 1954; Fuller and Burbidge, 1981; Garstone, 1978; Gibson, 1908; Hatcher and Walker, 1984; Sandland, 1937; Serventy, 1943; Tarr, 1959; Warham, 1956; Wilson *et al.*, 1977).

The islands have a low wind and salt-pruned heath vegetation composed primarily of woody, salt-tolerant schlerophilous shrubs and sub-shrubs, plus annuals in season, and several introduced species including grasses. At least 130 species of plants have been noted (Gardner, 1949; Hatcher and Walker, 1984; Storr, 1960). There are small stands of mangroves on several of the islands. The White Mangrove *Avicennia marina* provides the sole nesting habitat for the Lesser Noddy Tern.

The terrestrial fauna is remarkably diverse, given the small size of the islands. Species numbers are related to area, being highest on the Wallabi Islands. Most notable is the endemic Tammar Wallaby *Macropus eugenii* (Main, 1967), the endemic lizard *Egernia stokesii stokesii* (Kitchener and How, 1982), the Southern Bush Rat *Rattus fugiceps* (Storr, 1960), the Brush Bronzewing *Phaps elegans* (Storr and Ford, 1959), the Spotted and White-breasted Scrub Wrens *Seriornis maculatus* and *S. frontalis*, and the Painted Quail *Turnix varia*. In addition, common rats, rabbits and the domestic cat have been introduced to the islands by man.

**Scientific Importance and Research** The scientific importance of the Houtman Abrolhos was first recognized by Charles Darwin in reference to the growth of coral reefs, although he never visited them (Darwin, 1842). The noted naturalist Saville-Kent drew specific attention to the potential of the Abrolhos for geological and biological studies near the turn of the century (Saville-Kent, 1897). The first scientific expedition was led by W.T. Dakin in 1919 (the Percy-Sladen Trust Expedition, Dakin, 1919). This was followed by five expeditions from Aquinas College in Perth between 1965 and 1970 (O'Loughlin, 1965, 1966 and 1969; Green, 1972), and two from the Western Australian Museum in 1977 and 1978 (Wilson *et al.*, 1977). The latter study utilized facilities established by the Maritime Archaeology branch of the Museum at the Wallabi Group in 1972. These expeditions, plus numerous other visits by museum staff have provided semi-quantitative data on the distribution and abundance of many taxa; work is ongoing, with numerous publications in preparation.

The Commonwealth Scientific and Industrial Research Organisation (CSIRO) established a field station at Rat Island (Easter Group) in 1970 to monitor the recruitment of Rock Lobster (Chittleborough and Phillips, 1975). As part of the Coastal Ecology Program initiated in 1979, the CSIRO Marine Laboratories in Western Australia conducted a research programme that was abruptly terminated in 1983 as the result of a change in CSIRO policies. Publications resulting from this work include an assessment of nutrient concentrations within the lagoons (Crossland *et al.*, 1984), the carbon and nutrient dynamics of reef flats and lagoonal patch reefs (Johannes *et al.*, 1983b; Smith, 1981), the growth, physiology and genetics of some common corals (Crossland, 1981 and 1984; Stoddart, 1984), the biomass of benthic algal communities (Hatcher and Rimmer, 1985; Hatcher and Walker, 1984; Hatcher *et al.*, in press; Rimmer, in prep. c), and the physiology, ecology and community impact of herbivorous gastropods and fish (Hatcher and Rimmer, 1985; Rimmer, 1986; Rimmer, in prep. b; Rimmer and Hatcher, in prep.; Rimmer and Wiebe, in prep.).

Applied studies of the commercially exploited speceis at the Abrolhos have periodically been undertaken by the Western Australian Marine Research Laboratories. These include the population dynamics of the Rock Lobster (George, 1957; Morgan, 1972, 1974a and b, 1980) and the Saucer Scallop (Joll, 1985), and the food habits of the Bald-chin Grouper (Walker, 1983). At present (1987), there is only one basic research project (federally funded, based at the University of Western Australia) being actively pursued in the Abrolhos (Hatcher, 1985).

The Houtman Abrolhos are the southernmost coral reefs in the Indian Ocean, and are one of the best examples of luxuriant and diverse coral growth at high latitude. The unique geology, physiography and ecology of these coral reefs make them ideal testing grounds for biological and ecological hypotheses (e.g. Hatcher, 1985; Johannes *et al.*, 1983a; Main, 1967). These include: 1) The growth, development and evolution of coral reef structures as a function of long term variation in sea level and temperature. 2) Factors controlling patterns and magnitudes of secondary production on coral reefs. 3) The relative importance of biotic versus physical determinants of benthic community structure on coral reefs. 4) Factors controlling the biogeographic limits of marine plants and animals.

Besides the natural significance of the reefs, the Abrolhos have great historical and maritime archaeological significance. They are the site of European man's earliest and bloodiest encounters with the Australian continent. Extensive research has been conducted into five of the 16 known shipwrecks of historical importance at the Abrolhos (dating from 1629) by the Maritime Archaeology Section of the Western Australian Museum since 1972. Numerous artifacts and culturally significant sites remain on the islands and reefs of the area (Bevacqua, 1974; Dixon, 1972; Green, 1975, 1976 and 1977; Green and Pearson, 1975a; Ingleman-Sundberg, 1975, 1977 and 1978 a and b; Quilty, 1978; Spooner and Vickery, 1981; Stanbury, 1983).

The state of knowledge concerning the Abrolhos as reef ecosystems is extremely poor. The hydrographic charts are based on 100 year old surveys, and are virtually useless. There exists no meteorological data directly applicable to the area, and hydrological data has been collected for only one group of islands. The geological basis for the reefs' existence is poorly known; no cores have been taken. Perhaps most unfortunately, the ecological basis for the reefs' continued existence, and for the extraordinary yields of commercially exploited organisms is not understood. Despite the lack of knowledge, and the obvious value of this singularly interesting area, research effort has been minimal.

**Economic Value and Social Benefits** In the past, several of the islands were mined extensively for surface deposits of phosphatic rock (Guano) (Forrest, 1879; Hatcher and Walker, 1984; Stanbury, 1982). Information gathered from the numerous shipwrecks is well presented to the public in several museums throughout the state, and has been the basis of several books (e.g. Drake-Brockman, 1957 and 1963; Edwards, 1966 and 1970).

At least 15% of Australia's most valuable single species fishery (Western Rock Lobster) is taken from the Abrolhos reefs, although they constitute only about 3% of the total area fished (Hatcher, 1983 and 1985; Hatcher and Walker, 1984). The catch is remarkably stable, and has increased progressively from 1.1 to 1.9 x $10^6$ kg a year over the past 25 years (Anon, 1964; Sheard, 1962). It has a current landed value of about $10 x $10^6$ per year (Hatcher and Walker, 1984). The value of the associated support industries is of the same order.

A large, and rapidly increasing catch of a few species of fin fish are taken from the area as well. The yield per unit area from these fisheries is considerably greater than on the coast nearby, and is amongst the highest recorded for monospecific fisheries in any coral reef ecosystem studied to date (Hatcher, 1983 and 1985). Scallops are sporadically trawled from the seabed surrounding the reefs. The catch is highly variable from year to year (nil to 8 x $10^5$ kg a year) (Joll, 1985).

The islands and their associated reefs are increasingly popular destinations for yachtsmen, divers, and amateur fishermen but no tourist facilities exist at the Abrolhos, and the development of these activities has not been encouraged. Hence access and accommodation must be on boats. The area provides an interesting and unique recreation base for the ca. 200 holders of lobster fishing licenses (and their families and friends) who have the privilege to build accommodation and reside on certain islands (Baird, 1981).

**Disturbance or Deficiencies** The Abrolhos has a long history of human disturbance. The first shipwreck was in 1629 (Green, 1975), and several of the islands were denuded, strip-mined and inhabited by large populations of miners during the late nineteenth century (Hatcher and Walker, 1984; Stanbury, 1982). These activities, plus the introduction of plant and animal pests has led to the reduction and extinction of some native species of fauna and flora (Johnston, 1982). There has not been a large shipwreck since 1908, and no commercially exploitable deposits of Guano remain. Since about 1950, the major human impact on the area has been the rock lobster fishery, and its associated effects due to the ca. 13 million cray pot deployments per year, and the waste generated by the ca. 1000 inhabitants of the 220 permanent camps on 22 islands during the ca. 3 month fishing season. In addition, the fin fishery is open to professional and amateur fishermen all year, and effort has increased rapidly in recent years, particularly with the widespread use of drop lines (Hatcher, pers. obs.; Johnston, 1982). Scallop trawlers often anchor in the lagoons to shuck their catch during the season, thereby introducing non-resident species to the area. Recently, spearfishing by amateur divers based on tour boats has resulted in the removal of all large fish from certain patch reefs (Hatcher, pers. obs.). The use of nets and trawls in the area around the Abrolhos is a source of mortality to sea turtles, which are regularly found floating headless in the lagoons after being cleared from nets (Hatcher, pers. obs.).

Limited exploration for hydrocarbon reserves has been conducted in the Abrolhos area. In 1968, the British Petroleum Co. drilled on the NE side of Gun Island (Pelsart Group) (Abrolhos Oil Co., 1968). In 1976 several permits were granted to carry out seismic surveys and to drill for hydrocarbons. Since then, five surveys have been completed, and two offshore wells drilled without positive result (Johnston, 1982).

The coral communities of the Abrolhos are particularly susceptible to physical damage (e.g.: storms, lobster pots, anchors) in comparison to corals of tropical reefs, due to their structural fragility, slow growth rates, and susceptibility to competition from macroalgae (Crossland, 1981 and 1984; Hatcher, 1985 and in press).

**Legal Protection** The islands of the Abrolhos (to the low tide mark) are "A-Class" Reserves under Western Australian legislation (Reserve # A20253) vested in the Ministry of Fisheries. All terrestrial species are 100% protected. Of the marine fauna only cetaceans, undersized individuals of certain fish species and the commercial scallop and rock lobster stocks receive protection from exploitation out of fishing season. Entry to the rock lobster fishery is limited. Fishermen holding licences are permitted to construct buildings and jetties on certain islands in each Group, and may reside there with employees and families. All others (with the exception of approved research personnel) are not permitted to stay overnight on the islands. Construction and sanitation on the inhabited islands is regulated, and pest eradication programs are implemented (Young, 1981). Access to the marine environment, and to unprotected biological resources is virtually unrestricted.

**Management** The authority responsible for the islands and commercially exploited fish stocks is the Western Australian Department of Fisheries (108 Adelaide Tce., Perth, W.A. 6000) which until 1985 had sole jurisdiction over the area. Recently provision has been made for this Department to regulate other activities in the area through by-laws. There is no comprehensive management strategy or integrated usage plan for the Houtman Abrolhos. Unlike other reef areas, management has been based primarily on the effective exploitation of commercial fish stocks, and State supported, management oriented research has addressed only related topics. There are no wardens, interpretive centres or on-site facilities for the use of the public. Enforcement is restricted to periodic visits by a fisheries patrol vessel based in Geraldton. However, in 1986, an Interdepartmental Management Committee (with representatives from the State Departments of Fisheries, Mines and CALM) was set up to advise the Minister of Fisheries on management policy and an Abrolhos Consultative Committee was established.

**Recommendations** Four formal sets of recommendations have been put forward to foster the conservation and improve the philosophy and basis for management of the Abrolhos in the decade spanning 1974-1984. These are:

1. The "Conservation Through Reserves Committee" report to the Western Australian Environmental Protection Agency, 1974.
2. The "Proposed Aquatic Reserve: Houtman Abrolhos", Section 30 of the Fisheries Act, 1905-1975, Western Australian Department of Fisheries and Wildlife Public Information Bulletin (1978).

3. "A Report on the Houtman Abrolhos", prepared by the Geraldton Mid-West Regional Development Committee, September 1982.
4. The "Proceedings of a Workshop on the Houtman Abrolhos", by the Western Australian branch of the Australian Marine Sciences Association, 1984.

All of the documents recognize the inherent value of the Abrolhos, and recommend increased protection from human impact, extension of protection to marine habitats and species, and improved management approaches. The findings of the most recent workshop, held by scientists and interested people under the auspices of the Australian Marine Sciences Association in 1983, summarise the management goals:

1. The Royal Australian Navy be requested to complete the compilation and publication of the hydrographic survey conducted in the area by HMAS Moresby during 1978 as a matter of high priority.
2. Continued co-operation of the Australian Survey Office be solicited for completing the hydrographic survey in those segments omitted by the RAN survey.
3. The appropriate authorities be requested to give high priority to the establishment of a weather station on Pelsart Island.
4. Studies of the physical oceanography in the Abrolhos area be encouraged and supported financially.
5. The "Report on the Houtman Abrolhos" submitted by the Mid-West Regional Development Committee to the State government in September 1982 be given careful consideration, and released as a public document; in particular, the recommendations for a single management authority using a reserve zoning approach, no island-based tourism, and increased surveillance are supported.
6. The relevant state authority, in consultation with environmental managers and scientists with experience of the Abrolhos, identify areas of priority research as a guide to scientists working, or intending to work there.
7. Monetary and logistic support be provided (by direct or indirect means) to stimulate appropriate research at the Abrolhos.
8. The Western Australian Museum be asked to liaise with other government agencies and then provide an interim set of usage guidelines (similar to that commissioned for Rowley Shoals) for immediate publication and distribution.
9. A comprehensive Reserve Management Plan be drawn up for the terrestrial and marine components of the Abrolhos ecosystems considered together, as soon as possible.
10. A Reserve Management Officer be stationed at the Abrolhos as soon as possible.

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## KIMBERLEY COAST RESERVES AND ADJACENT REEFS

**Geographical Location** Reefs and islands adjacent to the north-western coast of Australia between Broome (17°58'S, 122°14'E) and Wyndham (15°28'S, 128°06'S) including the Bonaparte and Buccaneer Archipelago, Holothuria and Lacepede Reefs (16°52'S, 122°08'E), and Adele (15°31'S, 123°09'E) and Browse Islands (14°07'S, 123°33'E).

**Area, Depth, Altitude** Total area of about 72 000 sq. km; offshore reefs and islands rise from depths ranging from 45 to 110 m on the outer edge to much shallower depths adjacent to the mainland. Many reefs and shoals are continuously exposed or emergent only during low tides. Islands such as Adele and Browse are low, sand-cay, coral-rubble features which rise only a few metres above the high-tide mark. Coastal continental islands tend to be hilly, the highest reaching about 100-150 m.

**Land Tenure** A combination of Commonwealth, State, and private leasehold.

**Physical Features** The Kimberley region has an extremely rugged, irregular coastline with steep rocky shores and numerous bays and fiord-like inlets. Adjacent to the coast there are numerous small islands, reefs and shoals. Further offshore there are a few low relief desert islands such as the Lacepede group, or coral cays including Adele and Browse Islands. Coastal reefs are strongly influenced by turbid discharge from numerous rivers and smaller streams, and by a huge tidal fluctuation of up to 6-7 m. The climate is tropical with heavy monsoonal rainfalls between November and March.

Adele and Browse Islands rise from about 60 and 110 metres respectively from the middle portions of the continental shelf. Both are limestone platforms with a central sandy area, intermediate zone of shingle rubble, and an outer margin of active coral growth with some spur and groove formation shelving into deeper water. Reefs closer to the coast such as those at the Lacepedes and Holothuria Reefs are large platform and fringing reefs. Those closest to the coast are influenced by the contours of the Pre-Cambrian basement, and their formation is described by Bassett-Smith (1899) and Fairbridge (1953). The continental islands, chiefly those in the Buccaneer and Bonaparte Archipelagos, are also composed of Pre-Cambrian rocks and are mainly surrounded by fringing coral.

**Reef Structure and Corals** No detailed information.

**Noteworthy Fauna and Flora** The area includes a wealth of coral reef-dwelling organisms but these are largely unstudied. There are large tracts of mangal providing refuge for the marine crocodile *Crocodylus porosus*, sawfish *Pristis sp.*, giant barramundi *Lates calcarifer* (a popular food fish), mud crab *Scylla serrata*, and a number of bird species. The offshore islands are important nesting sites for a number of sea birds including terns, boobies, shearwaters, and tropicbirds and also serve as vital resting stops for migrant species such as dotterels, plovers and turnstones. The outer coral cays and closer islands including the Lacepede group are important breeding grounds for marine turtles. A survey of the Prince Regent River Reserve has been carried out by Miles and Burbridge (1975).

**Scientific Importance and Research** Teichert and Fairbridge (1948) wrote "the coral reefs of north-western Australia are without doubt among the least known in the world," and this statement is still true. The area is little known due to its remoteness and harsh environmental conditions, typified by huge tides and often turbid waters, but it offers tremendous research potential on account of its combination of continental islands, associated coral reefs, massive tides, and rich fluvial discharge. The Western Australian Museum has a vested interest in this region and brief collecting visits have been made in recent years; there are plans for future activities.

**Economic Value and Social Benefits** Currently the area is visited by a relatively small number of anglers and divers. The rugged Kimberley coast has tremendous potential for recreational anglers, but will probably be slow to develop because of its remoteness and the high cost of air travel and charter fishing boats. There are few entry ports as the coast is virtually uninhabited. There is potential for trawl fishing, particularly on the extensive Sahul Shelf and in the larger bays and inlets near shore. Experimental fishing in deep water off Browse Island resulted in significant catches of scampi *Metanephrops boschmani* which fetches a high price on the world market.

**Disturbance or Deficiencies** There are few man made disturbances as the region is mainly uninhabited and seldom visited. There was an iron-ore mining operation on Cockatoo Island (16°06'S, 123°37'E) but this ceased operation in late 1984. The coast is occasionally used for military manoeuvres and there is a possibility that the Cockatoo Island facilities will be taken over by the Defence Department. The area is seldom visited by Indonesian fishermen, unlike other reefs on the edge of the continental shelf. The main natural disturbances are heavy monsoon flooding and cyclones which may have devastating local effects on coral reefs.

**Legal Protection** Nearly all of the mainland coast is Aboriginal Reserve land vested in the Aboriginal Lands Trust of Western Australia. Proceeding north and east of Broome these include the following reserves: Beagle Bay, Kunmunya Admiralty Gulf, Kimberley, Kalumburu, and Forrest River. A number of flora and fauna reserves with control vested in the Western Australian National Parks and Nature Conservation Authority have been set aside. These include an "A-class" nature reserve at Coulomb Point (reserve No. A29983) and "C-class" reserves at the Lacepede Islands (No. C7279), Swan Island (No. C34257), Prince Regent River (No. C27164), Pelican Island (No. C29541) and Low Rocks (No. C33832), all vested in the Western Australian National Parks and Nature Conservation Authority. These are relatively tiny areas in relation to the entire coastline and protection is mainly terrestrial, extending seaward to the low tide mark. There is no legal protection for most of the offshore reefs and shoals.

**Management** Aboriginal reserves which comprise most of the Kimberley coast are controlled by the Aboriginal Lands Trust of Western Australia. Management of nature reserves is under the Western Australian Department of Conservation and Land Management, P.O. Box 104, Como, W.A. 6152.

**Recommendations** Legislation is required to establish marine reserves and to extend protection to subtidal reefs in existing reserves, but extensive biological surveys would first be necessary. Comprehensive biological collections are needed from the area not only from the standpoint of basic faunal documentation, but in order to achieve a much needed understanding of distribution and migratory patterns for the northern Australian biota.

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## LOWENDAL ISLANDS NATURE RESERVE, MONTE BELLO ISLANDS AND ADJACENT REEFS

**Geographical Location** Monte Bello Islands lie 120 km west-north-west of Dampier, 80 km north-west of Cape Preston; 20°20-20°33'S, 115°27-115°37'E. Lowendal Islands lie about 8 km south of southernmost island in Monte Bello group; 20°35-20°41'S, 115°31-115°35'E.

**Area, Depth, Altitude** The Monte Bellos consist of about 200 islands most of which are rocky islets only a few metres in diameter, although some are larger such as Trimouille Island which has an area of 492 ha, and reaches an altitude of 37 m and Hermite Island which has a land area of 939 ha, and reaches an altitude of 29 m. The Lowendals include about 30 rocky islets of only a few metres diameter and have a total land area of 300 ha; the highest point is 20 m.

Water surrounding the Monte Bellos varies in depth from 0.5-5.0 m and to the east, north and west of the islands there is a sharp drop off to 30 m. Water is shallower between, and to the north and south of the Lowendals; the drop-off is more gradual in the east and west than that at the Monte Bellos. Tryall Rocks (Trial Rocks) 13 km north-west of the Monte Bellos rise from about 20 m and are exposed at a 2.7 m tide.

**Land Tenure** The Monte Bello Islands are Vacant Crown Lands administered by the Department of Defence on behalf of the Federal Government (Department of Resources and Energy). Due to atomic testing carried out during 1952 and 1956, access is restricted. Responsibility for these islands is to be returned to the State of Western Australia. The seas around both island groups are currently registered under various petroleum leases and permits.

**Physical Features** The Monte Bello and Lowendal Islands lie, with Barrow Island, on a submarine ridge extending roughly northwards from the mainland near Onslow. Composed of Quaternary beach sands and outcropping red or buff calcarenite, the islands closely resemble the adjacent mainland coast.

The island groups lie within an area of low and unpredictable rainfall with an annual average of about 100 mm, falling mostly in summer (November to April) during tropical cyclones (averaging 1.5/year) and thunderstorms. Storms due to steep pressure gradients occur from May to September. Dew formation is probably a significant factor in the survival of both plants and animals. The air temperatures of the islands range from summer maxima of between 32°C to 40°C to a winter maximum of 19°C or occasionally lower.

In summer surface winds in this pseudo-monsoonal region vary from north-west to south-west at speeds of 4 to 8 m/sec. In winter the system is dominated by a steady pattern of south-east air flow which high pressure cells do little to disturb except to cause a change in wind speed which typically varies from 2 to 8 m/sec. The daily cycle of sea/land breezes is often masked by the synoptic air flow.

Water temperatures range from over 20°C in winter to about 30°C in summer, with only a slight drop through the water column to about 12 m. Salinity is almost constant through the water column at about 35 ppt as the tidal flow ensures complete mixing, except in the lagoons (narrow embayments) where the water may become hypersaline. The tidal regime incorporates a semidiurnal cycle with little diurnal inequality. The tidal range in this region increases going north (Easton, 1970) and at the Monte Bello Islands reaches about 3.5 m on spring tides. The tidal range at the Lowendals is slightly lower. This system is complicated by the shoaling effects of the bathymetry to give complex local water flows (Holloway, 1983). The tidal flow is about 35-40 cm/second, with maxima occurring midway between high and low tides, particularly spring tides.

Wave action is generally strong only to the west and north of the Monte Bello Islands which are themselves sheltered by offshore reefs. The Lowendals are much more sheltered though a strong tidal flow ensures constant water replacement. By comparison, Tryall Rocks are subject to strong and complex wave action and heavy tidal rips.

The Monte Bello Islands lie around the perimeter of a shallow lagoon and the much indented islands further shelter embayments and channels. This physiography produces a large area of shallow water which is sheltered to a degree otherwise unknown along the north-west coast of Australia. The Lowendal Islands are more scattered and the water flow is less impeded.

**Reef Structure and Corals** Discontinuous and chanelled fringing reefs, particularly off the western and northern coasts of the Monte Bello Islands and well to the west of the Lowendals, can be covered with luxuriant soft and hard coral growth, particularly of fragile, presumably fast growing tabular and staghorn *Acropora* colonies. Smaller patches of similarly rich fringing reefs occur off the eastern coasts of islands of the two groups which lie along the eastern edge of the submarine ridge. Large *Porites* bommies (to 5 m diameter) grow from the limestone reef running south of Trimouille Island to the Lowendal Islands. Less luxuriant coral growth, associated with algal and seagrass beds is found in the more sheltered waters between the islands. Tryall Rocks to the north-west do not have any appreciable coral growth associated with them.

Brief sampling at Monte Bello in December 1979 has resulted in a list (L.M. Marsh, pers. comm., March 1985) of 66 species in 30 genera of scleractinian corals. The non-scleractinian genera *Millepora* and *Heliopora* were not recorded. This list is small compared with those recorded for Ningaloo Reef (44 genera), the Dampier Archipelago (48 genera) and the Rowley Shoals (52 genera) but is believed to be largely due to limited sampling. The corals of the Lowendals have not been surveyed.

**Noteworthy Fauna and Flora** Mangals are present, though often of small size, along many of the sheltered, often rocky shores of the Monte Bellos. The species are reported to include *Avicennia marina, Rhizophora mucronata, Ceriops tagal* and *Bruguiera rheedii* (Burbridge, 1971; Hill, 1955; Montague, 1914). Burbridge (1971) states that the birds of these Bello mangals are more diverse than in the pure stands of *A. marina* at Barrow Island to the south. Only a few observations of breeeding seabirds have been made on the Monte Bellos (Burbridge, 1971) and colonies are small compared with the large aggregations on other north-west islands (Serventy and Marshall, 1964). Sheard (1950) records sighting dugongs *Dugong dugon* and mating Green *Chelonia mydas* and Hawksbill *Eretmochelys imbricata* Turtles in the shallow waters around Monte Bello Islands in August, and Serventy and Marshall (1964) record mating Green turtles in September 1958.

Twenty-eight species of fish were recorded from the Monte Bellos by Hill (1955) but G. Allen (pers. comm., March 1985) reports that a preliminary survey indicated that the fauna is essentially similar to that of the Dampier Archipelago and would be expected to include about 400 onshore species. His records indicate that there is an abundance of angling species including grouper (Serranidae) and snapper (Lutjanidae). Little is known of the fish fauna of the more exposed western reefs. Allen emphasizes that the extensive protected waters within this island group are unique to the north-west coast of Australia and have a fish fauna of low diversity but sometimes high abundance. Sheard (1950) had also noticed the large shoals of mullet (Mugilidae) and other fishes in the "lagoons" and the very numerous juvenile fishes in the shallows. B. Hutchins (pers. comm., March 1985) reports a fish fauna typical of coral reefs, with a greater diversity of triggerfish (Balistinae) and wrasse (Labridae) species than has been found in the more completely surveyed Dampier Archipelago waters.

The echinoderm fauna of the Monte Bello Islands, though only briefly surveyed in 1979, is reported (Marsh pers. comm., March 1985) to include 10 species of asteroids, 10 of echinoids, 4 holothurian species and one species each of crinoids and ophiuroids. Rathburn (1914) recorded 28 species of stalk-eyed crustaceans from specimens collected by Montague, including two new species of xanthid crab and a new species of palaemonid shrimp. The list is only a small portion of the crustacean fauna of the area, which includes four species of rock lobster.

Molluscs from the Monte Bellos were collected by Montague in 1912, and from that collection, Iredale (1914) compiled a list of 44 species of bivalves and gastropods including two new species. He states that about 50 additional species would be represented in a collection made earlier by Mr T. Haynes, who had formerly held a lease for the cultivation of pearl shells. A new species of Dumpling squid was described by Robson (1914) from one of three cephalopod specimens collected by Montague (until recently the only known specimen of this species). More recent but still superficial collecting has added about 100 species of epifaunal macromolluscs to this list (Slack Smith pers. comm., February 1985).

The fauna and flora of the Lowendal Islands have not yet received even this superficial attention, although Butler (pers. comm., February 1985) reports a very wide diversity of marine habitats.

**Scientific Importance and Research** These essentially oceanic reefs serve as a "stepping stone" between the more southern fringing reefs off North West Cape and

Barrow Island and the true oceanic reefs of Rowley Shoals, Scott Reef etc. for biota unable to withstand the turbid and variable waters further inshore. Their physiography, associated with strong water movement, provides a diversity of habitat unusual in this area. The frequency of cyclones probably permits the persistence of certain ephemeral species. The Tryall Rocks are the site of Australia's oldest known shipwreck: the "Trial" foundered there in 1622 (Green, 1977).

**Economic Value and Social Benefits** A pearl culture lease is operating on the Monte Bello Islands between Hermite and Campbell Islands (authorised by W.A. Department of Fisheries and Wildlife). Recreational line and spearfishing is popular and large quantities of fish and rock lobsters are taken from both the Monte Bellos and the Lowendals (Butler pers. comm., February, 1985). Stephenson's Channel at Hermite Island is used as a safe anchorage for vessels, including those from Barrow Island, during cyclonic weather (Burbridge pers. comm., March 1985).

**Disturbance or Deficiencies** The current limitations on visiting the Monte Bellos Island area and the protected status of the Lowendal Islands lessen the impact of tourism at present but the growing popularity of fishing, diving and shell collecting activities operating out of Dampier and Onslow will probably become a problem. Oil exploration activities in surrounding waters which are currently registered under various petroleum exploration leases and permits introduce a potential hazard particularly in the Lowendals (Burbridge pers. comm., March 1985). Reports from a series of surveys carried out by the Department of Defence indicate that there is no significant residual radiation hazard from the atomic tests of 1952 and 1953 on the Monte Bellos (Anon., 1979 and 1983).

The rocky reefs can be stripped bare by strong wave action during cyclonic weather. Those around the Lowendals have been extensively damaged by Crown-of-Thorns starfish *Acanthaster planci* (W.H. Butler pers. comm., February 1985). Seismic work has been carried out on some of the reefs (particularly around the Lowendals) but recolonization of damaged areas is reported to be rapid.

**Legal Protection** The Lowendal Islands were declared a C Class Nature Reserve (No. C33902) for the Conservation of Flora and Fauna on the 5 March, 1976. Access to the Monte Bello Islands is limited and prior permission to visit must be obtained. An oyster lease is currently (March 1985) held in this area.

**Management** The responsibility for the Lowendal Islands is vested in the Western Australian National Parks and Nature Conservation Authority and management is through the Department of Conservation and Land Management, P.O. Box 104, Como, W.A. 6152. Permission to enter the Monte Bello Island Group has to be sought from the Naval Officer (Commanding), HMAS "Stirling", Garden Island, W.A.

**Recommendations** A full marine ecological survey should be carried out. The urgent need for such a survey is demonstrated by the planned installation of oil drilling and storage equipment near to and on the Lowendals. The multiple usage planned for the Monte Bellos should not be proceeded with until the adjacent reef systems can be examined, assessed and perhaps zoned. It is intended that responsibility for the Monte Bello Islands will be returned to the State of Western Australia and that some degree of protection will be afforded to them under State legislation, for recreation in a natural setting and, in the case of Hermite Island, for reintroduction of indigenous mammals.

## MUIRON ISLANDS RESERVE AND ADJACENT REEFS

**Geographical Location** Eastern Indian Ocean, 15 km north-west of North West Cape; 21°40'S, 114°23'E.

**Area, Depth, Altitude** South Muiron Island 7.5 x 1.1 km; North Muiron Island 4.5 x 1.4 km; total area of approx. 14 sq. km; max. alt. 18 m. The islands are surrounded by relatively shallow waters; the accessible inshore areas are 1-8 m deep.

**Land Tenure** Shire of Exmouth jointly with the Western Australian Government.

**Physical Features** The Muiron Islands are low, limestone islands with long beaches on the south-eastern sides, and rock-strewn slopes along their north-western coasts. A wide navigable channel separates the two.

**Reef Structure and Corals** On the exposed north-western coasts, a prominent spur and groove reef system is present. The reef spurs are heavily covered with hard and soft corals, while the grooves and reefs seaward of these are noticeably poorer in terms of coral cover. The more protected south-eastern sides, particularly on the south island, have a series of shallow lagoons protected by offshore reefs, which are particularly luxuriant, being comparable with the best in other coastal areas of Western Australia. In most areas, reef formations are replaced at depths of about 6 m by gently sloping sandy bottoms. One exception to this is near the south-western corner of the south island where coral growth is minimal, and the bottom is steeply sloping limestone, pock-marked with shallow depressions. The most prominent growths here are stunted weeds (tide rips are particularly strong in this area).

**Noteworthy Fauna and Flora** Only the fish fauna of the islands has been surveyed (Hutchins, 1977), 330 species having been recorded so far. With further work, the list could be increased by at least another 70 species. The inshore fish fauna of these islands appears to be an extension of the nearby Ningaloo reef fish fauna.

**Scientific Importance and Research** J.B. Hutchins and J. Trendall of the Western Australian Museum surveyed the inshore fishes at South Muiron Island in June, 1977. Numerous collections of trawl-caught species have also been taken from the nearby prawn trawling grounds in Exmouth Gulf. From these, several new fish species were discovered and subsequently described, while other possible new species are currently under investigation.

**Economic Value and Social Benefits** The islands are often visited by fishermen, both recreational and professional. Sports divers have been attracted to the area by the diversity of the marine life. Many spend short periods of time camped on beaches at the northern end of the south island which is favoured because of its reasonably sheltered anchorage. This is also often used by commercial fishing boats that operate in the area.

**Disturbance or Deficiencies** Disturbance to the marine environment is apparently minimal with the present low level of human activity in the area. Any increase in tourist numbers to Exmouth, however, could produce far greater pressures on the fauna in the islands' more accessible areas.

**Legal Protection** The islands are a C Class Fauna and Flora Reserve (No. C31775), vested in the Western Australian National Parks and Nature Conservation Authority.

**Management** The reserve is managed through the Western Australian Department of Conservation and Land Management, P.O. Box 104, Como, W.A. 6152.

**Recommendations** Due to the similarity between the marine faunas of the islands and the Ningaloo area, the Muiron Islands have been suggested for inclusion in the Ningaloo Marine Park.

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## NINGALOO MARINE PARK

**Geographical Location** The Ningaloo reef tract runs parallel to the west coast of North West Cape Peninsula for approximately 260 km between North West Cape in the north (21°47'S) and Amherst Point in the south (23°34'S).

**Area, Depth, Altitude** On average the tract is several hundred metres wide; on the seaward side it drops off steeply to about 10-15 m depth. On the landward side there is a shallow lagoon 2-4 m deep with longshore channels of up to 12 m depth.

**Land Tenure** Tenure of the reef and adjacent was until recently held by numerous government agencies, control being vested in them under thirteen State and seven Commonwealth Acts. Some of the adjacent land is a state National Park, some is pastoral lease and some is held under freehold title by the Commonwealth of Australia. With the establishment of the marine park, most of the area is now held by the Western Australian State Government and Australian Commonwealth.

**Physical Features** The Ningaloo reefs comprise a part barrier, part fringing reef system. On average, the reefs are 2.5 km off shore with a range of less than 200 m to 7 km. The reef tract and its precincts may be broadly divided into the following five major habitat units. The shelf, which is narrowest towards the north of the proposed Marine Park, becomes progressively wider further south. On its seaward side the reef drops off to a rocky bottom 8-10 m deep, which is often dissected by spur and groove structures. The bottom then slopes gently to 100 m about 11 km from the coast and 200 m about 44 km from it as far south as Point Edgar and becomes progressively less rocky and more sandy. The reef consists of a partially dissected basement platform of Pleistocene marine and aeolian calcarenite (or Tertiary limestone), which is covered by living and dead coral. The lagoon between the reef and the foreshore is protected from oceanic swells. Surf breaks continuously on the reef front in all but exceptionally calm conditions. This generates cells of circulation with water moving most of the time strongly and continuously over the reef on a broad front then passing into the lagoon where longshore currents form in deep channels and ultimately flow out through the passages or breaks that occur in the reef every few kilometres. These passages in many instances correspond with drainage systems and creeks on the coast. The lagoon bottom is usually covered by a thin veneer of sand with occasional areas of bare limestone. The foreshore consists of steep, generally narrow, sandy or pebble beaches interspersed with limestone rock platforms, some with rock cliffs up to 3 m high. At spring low tides gently sloping beachrock, mud or sand flats are exposed for a distance of up to about 200 m from the shore.

The tidal regime is semi-diurnal, although occasionally at neap tides a diurnal regime may occur. Maximum tidal range is 1.7 m at Point Murat with a mean difference between high and low tides of 1.0 m. The ocean currents off North West Cape have two distinct seasonal directions of flow (Carrigy and Fairbridge, 1954). In summer there is a northerly drift from the south. In winter, water flows southward as the Leeuwin current (Legeckis and Cresswell, 1981) which reaches the south coast of Western Australia. Seasonal variation in water temperature off the North West Cape peninsula is approximately 22°C to 29°C depending on seasonal conditions, averaging 26°C in summer.

The climate is semi-arid to arid with an average rainfall of 200-300 mm, and evaporation 1780-3050 mm a year. Rainfall occurs at any time during the year but averages are affected by periodic heavy rains associated with cyclonic disturbances. Because of the aridity of the hinterland, the reef experiences little turbidity, despite its proximity to the coast. The average daily air temperature for January is 23°C with a maximum of 37°C. In July the average minimum is 14°C and maximum 24°C.

**Reef Structure and Corals** The present coral communities are growing as a thin veneer on a Pleistocene basement of aeolianite and calcarenite including *in situ* fossil corals (Geol. Survey, W.A. pers. comm.). The reefs vary in height and little is emergent except at the lowest spring tides. The outer reef flat and upper slope are covered by low growing corymbose and small tabular *Acropora* with coralline algae. In places *Platygyra sinensis* heads make a prominent band on the reef margin. There is rarely an emergent boulder zone and the reef flats are covered with tabular *Acropora* spp., mixed coral communities or a short algal turf.

Back reef areas have a diverse coral fauna interspersed with sand patches. In places broad sand sheets extend toward the lagoon, in others the back reef drops steeply with a highly diverse coral fauna. Numerous isolated *Porites* coral pinnacles or "bommies" and reef patches are scattered through the lagoon, some up to 6 m high and 10 m across, and there is some *Sargassum*. There is a high degree of variability between different parts of the reef.

No quantitative studies have been made of coral community structure. Approximately 170 species in 44 genera of scleractinian corals have been recorded so far, compared with 52 genera and 180 species at Rowley Shoals. Ten genera of soft corals have been recorded.

**Noteworthy Fauna and Flora** Preliminary faunal surveys have resulted in records for the following groups: echinoderms 56 genera and 90 species (Marsh, 1980), molluscs approximately 600 species (Wells, 1980a, 1980b; Slack-Smith, 1980), and fish 234 genera and 480 species (Allen, 1980). Green Turtles *Chelonia mydas* have several extensive rookeries inside the reef and Hawksbill Turtles *Eretmochelys imbricata* are seen occasionally. Dugongs *Dugong dugon* occur in the lagoon and the migration route of the Humpback Whale *Megaptera novaeangliae* is very close to the reef at Norwegian Bay. The fauna is predominantly tropical Indo-West Pacific with a minor intrusion of temperate species. At Mangrove Bay there is a small, but well developed mangal where *Avicennia marina, Rhizophora stylosa* and *Bruguiera exaristata* occur. Mangroves occur in other creek mouths which are normally barred, particularly at Yardie Creek.

**Scientific Importance and Research** This is the longest tract of continental fringing reef in Australia. The only other extensive coral reef in close proximity to a western continental margin at a comparable latitude in the southern hemisphere, is the Grand Récif off the west coast of Madagascar. The W.A. Museum, partly in conjunction with the National Parks Authority, has examined the reefs and sampled the fauna at about 130 sites along the reef. However some areas are still very inadequately known and others have not been sampled. Preliminary inventories of the corals, echinoderms, molluscs and fishes have been prepared (W.A. Museum unpub. reports).

**Economic Value and Social Benefits** The Ningaloo reef tract is unique in Australia because of its proximity to the coast and its accessibility. Undoubtedly its major potential economic value lies in recreation and tourism. Estimated recreational usage in 1981/82 was 55 000 people, the majority of whom were engaged in dispersed, unregulated camping along the adjacent coast.

**Disturbance or Deficiencies** Recreational fishing pressure on the reef is heavy and almost unregulated and commercial collection of fish for aquaria, shells and coral has taken place extensively. Two petroleum tenements are current for the offshore seabed, covering all waters of the proposed Marine Park and the land component is subject to an onshore tenement. An onshore well, deviated to a target 5 km offshore, was drilled in 1980 but was non-productive and has been capped.

**Legal Protection** In 1987, the majority of the reef area and the adjacent coast is being declared a marine park. A small marine reserve incorporating approximately 453 ha and a section of the reef tract, located between Point Maud and Coral Bay, was established under the State Fisheries Act 1954. The reef bordering Cape Range National Park is included on the Register of the National Estate (Anon., 1986).

**Management** The marine park is being managed by the Western Australian Department of Conservation and Land Management (P.O. Box 104, Como, W.A. 6152). A multiple use management plan is to be developed affording various degrees of protection to the flora and fauna of the area.

**Recommendations** Recommendations for the area are given in May *et al.* (1983). The area has received funding under the Bicentennial programme for the development of an infrastructure, designed primarily to support tourism (Anon., 1986).

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## ROWLEY SHOALS RECOMMENDED MARINE NATURE RESERVES

**Geographical Location** The area includes three separate shelf atolls on the edge of the north-western Australian shelf approximately 300 km north-west of Broome: Mermaid Reef 17°7'S, 119°36'E; Clerke Reef 17°10'S, 119°20'E; Imperieuse Reef 17°35'S, 118°56'E.

**Area, Depth, Altitude** Mermaid Reef 14.5 km x 7.6 km; Clerke Reef 15.8 km x 7.6 km; Imperieuse Reef 17.8 km x 9.5 km. All three reefs drop off steeply to about 500 m on their western sides. On eastern sides there is a progression from north-east to south-west in the depth to which they drop off: Mermaid 440 m, Clerke 390 m, Imperieuse 230 m; this and a progressive decrease of lagoon depth (Mermaid 20 m, Clerke 8 m) may indicate that each represents a different stage of development (Berry, 1986; Berry and Marsh, 1985).

**Land Tenure** Western Australian State Government and Australian Commonwealth Government.

**Physical Features** Each shelf atoll comprises a lagoon or series of lagoons enclosed by a roughly ovoid reef. Mermaid has a series of sand cays which become exposed at low tide. The single lagoonal basin is connected to the sea by a deep passage about 35 m wide. Clerke and Imperieuse both have small, permanent unvegetated sand cays in the north and complex lagoonal systems with three basins, shallower than the Mermaid lagoon. On Clerke, the deepest basin is connected to the sea by three narrow passages. Imperieuse Reef has a poorly defined, narrow shallow passage in the north-east. It is likely that the Rowley Shoals are of similar age and structure to Scott Reef, another shelf atoll to the north-east which has been drilled through an entirely sedimentary sequence to a depth of 11 500 ft (3505 m), reaching the Upper Cretaceous (Wright, 1977). Assuming a similar structure to Scott Reef, formation of the Rowley Shoals was probably triggered by tectonic depression of the shelf in the mid-Miocene.

The region is in the monsoonal belt with prevailing westerly or north-westerly winds from about November to March and south-easterly or easterly trade winds from about April to October. The prevailing oceanic swell is from the south-west which results in wider reef formation on the western margins of each shoal. The semidiurnal tidal cycle and exceptionally high tidal range of about 5 m means that there is no localised surf zone and thus no well-defined algal reef crest. The reef flats are exposed at low tide. Because of the narrowness of the passages, the reef water is impounded within the lagoons at low tide resulting in a "basin" effect with the water inside them held at a level well above sea level outside. Currents through the passages are exceptionally strong. Surrounding water conditions are oceanic. Water clarity is high on the outer reef slopes, but is reduced in the lagoons. Water temperatures are tropical but no precise data are available.

**Reef Structure and Corals** Rowley Shoals have an oval, annular form with the reef on the western side two or three times as broad as that on the eastern side. On Mermaid, the outer reef flat, exposed at low water springs, is about 500 m wide. The back reef is of similar width and the sand sheet a further 1 km wide making a total width of about 2 km in contrast to the eastern reef which has a total width of approximately 600 m.

On Clerke the western reef is about 1500 m wide and the eastern reef 800 m wide. On the western side the outer reef slope has a rather barren wave swept spur and groove structure sloping to a coral covered ledge at 12 m, followed by a sheer drop-off to a ledge at 30 m with large coral covered "boulders", beyond which there is a 45° slope. The outer reef flat has a high energy coral assemblage including *Acropora palifera, Pocillopora eydouxi* and faviid corals, and encrusting coralline algae while the reef flat has a cover of living and dead coral with some algal turf. There is no well-developed boulder zone (Berry and Marsh, 1985). The back reef, at a lower level has a diverse coral fauna including *Acropora* in some areas and patches of seagrass, *Thalassia*, in others. The sand sheet has scattered coral patches. The eastern and northern sides of the atolls differ from the western side. In some areas there is more extensive coral cover on the reef flats, in others there are extensive areas of algal covered pavement. In places there are residual stacks of dead coral standing approximately 3 m above the reef flat. The outer reef slope on the east side has a spur and groove structure extending as alternating gullies, with sand and rubble bottoms and coral covered ridges to 30 m depth. The ridges have a diverse coral fauna including species of *Acropora, Porites, Diploastrea, Euphyllia, Pachyseris* and *Physogyra*, giving way to gorgonians and alcyonaceans on their lower faces. Between 20 and 30 m there is a steep slope (45°) with isolated coral pinnacles, and hard coral is sparse.

Imperieuse Reef has a complex lagoon partly infilled by mesh reef with a poorly defined shallow channel (Berry, 1986; Berry and Marsh, 1985).

Coral community composition and structure has not been studied. In a seven day survey, Veron (1986a) recorded 52 genera and about 180 species, mainly Indo-West Pacific species, showing a particular affinity with Indonesia. This is the richest coral fauna recorded thus far from Western Australia, although a recent survey of Scott Reef 400 km to the north-east, may reveal a similar and even more diverse coral fauna there.

**Noteworthy Fauna and Flora** A seven day survey by the Western Australian Museum in 1982 resulted in lists of 122 genera and 264 species of molluscs; 54 genera and 82 species of echinoderms; and 197 genera and 389 species of fish (Berry, 1986; Berry and Marsh, 1985). A high proportion were new records for Western Australia (e.g. 45% of the fish). The abundance and fearlessness of very large reef fish such as the serranid Potato Cod *Epinephalus tukula* was noticeable, indicating lack of exploitation. Rock lobsters (Palinuridae), sea snakes (Hydrophiidae) and volutes (Volutidae) were absent which is curious as all occur on Scott Reef.

**Scientific Importance and Research** Geomorphological studies were carried out by Carrigy and Fairbridge (1954), Fairbridge (1950) and Teichert and Fairbridge (1948). Recent hydrocarbon exploration has increased knowledge of the geology of North West Shelf as a whole (Hinz *et al.*, 1978; Jones, 1970; Kirk, 1977; Powell, 1976; Shafik, 1978; Stagg, 1978).

The fauna has received scant attention. Brief trips were made by individual members of the Western Australia Museum in 1971 and 1981 during which some collecting was done. In 1982, the museum returned with a team that concentrated on corals, echinoderms, molluscs and fishes and undertook a seven day preliminary faunal survey of Mermaid and Clerke Reefs (Berry, 1986). On the basis of this expedition it was concluded that the Rowley Shoals are important for a number of reasons. In the Western Australian context the fauna is oceanic and significantly different from that of coastal reefs. There is an interesting representation of Indian Ocean coral reef fauna and affinities with the Indonesian region not represented in Pacific reefs. The faunal communities are almost totally unexploited, and notable for the abundance of large reef fish and molluscs such as giant clams *Tridacna* spp. The reefs are of exceptional aesthetic value. They are considered to be geomorphologically the most perfect examples of shelf atolls in Australian waters (Fairbridge, 1950); the three Rowley Shoals also exhibit an interesting gradation in lagoon depth and structure that seems worthy of study. The tidal range (greater than 5 m) makes the Rowley Shoals (which faunistically are oceanic rather than shelf atoll) unusual, if not unique.

**Economic Value and Social Benefits** The shoals are probably the most accessible (by boat from Broome) of the offshore shelf atolls on the north-west shelf. For at least the last five years charter boat operators have been catering largely for game fishing parties and diving clubs and there is great potential for increased recreational visitation from Broome. There is an automatic weather station on the cay on Imperieuse Reef.

**Disturbance or Deficiencies** Indonesian fishermen operating sailing vessels (prahus) occasionally reach the Rowley Shoals, seeking beche-de-mer, trochus shell, and clam meat. However, because of the distance from Roti, their impact on Rowley Shoals seems to have been minimal. Taiwanese clam fishermen are a more serious threat. In 1984, a clam vessel apprehended at Mermaid Reef was found to contain 3 tonnes of clam meat in a concealed freezer compartment (Anon., 1985a). Anchor damage, inappropriate disposal of refuse and exploitation, particularly of reef fish and molluscs, as a result of increased charter boat visitation, is seen as a potential problem.

**Legal Protection** In 1982, limited protection was afforded to several species of large reef fish within one statute mile of the reefs by the W.A. Dept of Fisheries.

**Management** None at present although educational pamphlets with guidelines are issued to charter boat operators and some voluntary regulation occurs. Indonesian fishermen are discouraged from visiting the Shoals, although they are permitted to carry out traditional fishing operations at Scott Reef and Ashmore Reef. Regular aerial surveillance and patrols by naval vessels permit the W.A. Dept of Fisheries to monitor fishing activities in the area. Responsibility for the reefs is vested in the Western Australian Dept of Conservation and Land Management, P.O. Box 104, Como, W.A. 6152.

**Recommendations** On the basis of its faunal surveys, the Western Australian Museum recommended in 1983 that the Rowley Shoals should be declared a marine park. The Marine Parks and Reserves Selection Working Group has recommended that a series of Marine Nature Reserves be established.

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**SCOTT REEF AND SERINGAPATAM REEF**

**Geographical Location** 300-350 km from the Western Australian coast, approximately 23 km apart and forming part of the series of reefs along the edge of the north-western continental shelf that includes the Rowley Shoals 400 km to the south-west and Ashmore Reef 200 km to the north-east; Scott Reef approx. 14°5'S, 121°51'E; Seringapatam Reef approx. 13°40'S, 122°00'E.

**Area, Depth, Altitude** Both reefs drop off extremely steeply to the surrounding seabed at a depth of 300-700 m (further details below).

**Land Tenure** Western Australian State Government.

**Physical Features** Both are shelf atolls (Teichert and Fairbridge, 1948). Scott Reef consists of two separate major reef formations: North Reef, an annular structure (16.3 km x 14.4 km) which encloses a generally deep lagoon (maximum 21 m) connected to the ocean by one passage in the north-east and one in the south-west; and South Reef, a crescent-shaped reef, the "arms" of which subtend North Reef. The distance between the extremities of the arms of the crescent is 27.4 km, forming an open lagoon 35-55 m deep. There is a permanent, low, unvegetated sand cay (about 1150 m x 850 m) on a patch reef, ENE of the western arm of the reef, on which an automatic weather station is located. North and South Reef are separated by a trench 400-700 m deep. Scott Reef has been drilled through an entirely sedimentary sequence to a depth of 11 500 ft (3505 m), at which the Upper Cretaceous was reached (Wright, 1977). Significant hydrocarbon reserves were recorded (Anon., 1971). Reef formation has presumably been associated with gradual tectonic depression of the shelf and was probably triggered in the mid-Miocene.

Seringapatam Reef is an annular structure (8.0 km x 9.4 km) enclosing a lagoon of fairly uniform depth (20 m) with a maximum depth of 30 m. A poorly defined passage connects it to the ocean in the north-east (Berry and Marsh, 1985).

Tidal range is high (4.2 m MHWS) and the pattern is semi-diurnal. (Tidal predictions are available for Scott Reef). Other physical environmental information available is as for Rowley Shoals.

**Reef Structure and Corals** Scott and Seringapatam Reef appear to support a similar but possibly slightly more speciose scleractinian fauna than was recorded at the Rowley Shoals by Veron (1986a).

Seringapatam Reef has a slightly broader reef on the western side (1500 m) than on the eastern side (1200 m). On the south-east side there is a well developed boulder zone on the reef crest, beyond which the reef slopes gently seaward, the inner part covered by a short green algal turf, the outer part by encrusting pink coralline algae with few living corals. There is more coral at the reef edge on the tops of spurs; the grooves are covered by encrusting coralline algae. There is no information on other areas.

North Scott Reef is roughly pear-shaped with little difference in the width of the reef on the eastern and western sides. The western reef is 900-1650 m wide with about 150-800 m emergent at low water springs. The outer reef flat, covered with algal turf, occasional living coral colonies and a few boulders, slopes gently seawards. The inner reef flat has a low growing cover of living and dead coral with some algal turf. There is no distinct boulder zone. The back-reef at a lower level has a diverse coral fauna with sand patches. Towards the lagoon corals become more scattered and there is an extensive sand sheet before a steep sand slope to the lagoon. The eastern reef flat has extensive areas of emergent algal covered pavement, with scattered corals towards the outer edge. The upper slope has irregular surge channels between coral ridges and isolated coral hillocks to c. 30 m, beyond which is a steep scree slope with little coral. There are numerous coral pinnacles and patch reefs in the lagoon with a diverse fauna of massive and foliose corals Living corals include species of *Porites, Goniastrea* and *Heliopora* (Berry, 1986; Berry and Marsh, 1985).

South Scott Reef has a broad emergent platform on its south-western side but only small scattered areas uncovered at low tide on its eastern half. Where examined, on the south side, the emergent reef flat is 600 m wide and the total reef width is 2.2 km. In this area there is a narrow boulder zone on the reef crest beyond which the outer reef flat has a short green algal turf which gives way to a gentle slope covered with crustose coralline algae and very little coral. The broad reef flat is fairly sandy with some boulders, short algal turf, and very little coral. The back reef, at a slightly lower level, is sandy with scattered clumps of *Porites* and other corals and sparse seagrass. Coral patches in the lagoon near the reef have a diverse coral fauna (Berry, 1986; Berry and Marsh, 1985).

**Noteworthy Fauna and Flora** The fauna of Scott and Seringapatam Reefs appears to be slightly more diverse than at Rowley Shoals, especially in the number of fish species recorded (490) (Berry, 1986; Berry and Marsh, 1985). Sea snakes (Hydrophiidae) (at least five species), rock lobsters, (Palinuridae) and volutes (Volutidae) at Scott and Seringapatam Reefs occur here and are absent at Rowley Shoals. Three species of seagrasses were recorded. Green turtles *Chelonia mydas* nest on Sandy Islet.

**Scientific Importance and Research** The scientific importance of Scott Reef lies in the geophysical and physical environmental information available on it as a result of hydrocarbon exploration and its apparent great age (and probably also the other offshore atolls of the

North-West Shelf) compared with other Australian coral reefs. In addition to a 1984 Western Australian Museum Survey, biological collections have been made at Scott Reef by the R.V. "Alpha Helix" in 1972 and the R.V. "Callisto" in 1979, although reports on these apart from documentation of the sea snakes (Minton and Heatwole, 1975) are not readily available. Seringapatam Reef was visited by the R.V. "Professor Bogorov" in 1978 and unpublished reports on some faunal groups are available. Publications relevant to these reefs include Berry (1986), Carrigy and Fairbridge (1954), Fairbridge (1950), Hinz *et al.* (1978), Jones (1970), King (1827), Kirk (1977), Powell (1976), Shafik (1978) and Stagg (1978). Scott and Seringapatam Reefs undoubtedly represent important regional examples of coral reefs of high biological and aesthetic value. However, their importance needs to be placed in perspective by conducting biological surveys at Ashmore Reef and further work at Rowley Shoals (*see separate accounts*).

**Economic Value and Social Benefits** The primary potential economic value of Scott Reef probably lies in its hydrocarbon reserves. It has less potential for recreation as the Rowley Shoals, being less accessible from Broome, the principal tourist centre of the Kimberleys. The presence of large numbers of sea snakes, visible effects of exploitation by Indonesian fishermen and scarcity of large reef fish probably make it less attractive for recreational activities than Rowley Shoals, although aesthetically the coral reef may be just as spectacular.

**Disturbance or Deficiencies** Depletion of clams *Tridacna* and *Hippopus*, other large molluscs and beche-de-mer species of holothurians, especially *Microthele nobilis*, by Indonesian fishermen is evident on some reef flats (Berry and Marsh, 1985).

**Legal Protection** None.

**Management** None at present. Responsibility for these reefs is vested in the Western Australian Department of Conservation and Land Management, P.O. Box 104, Como, W.A. 6152.

**Recommendations** The regional biological importance of Scott and Seringapatam Reefs should be re-evaluated after surveys of Ashmore Reef and more work at Rowley Shoals.

# BAHRAIN

## INTRODUCTION

### General Description

Bahrain is a group of 33 low-lying islands, largely of limestone outcrop and desert, and a number of reefs between 15 and 20 miles (24-32 km) from the Saudi Arabian coast. Their total area is 255 sq. mi. (660 sq. km). The largest island is Bahrain itself (30 x 8-10 mi. (48 x 13-16 km)); the second is Al Muharraq, to the north-east. A bridge connects Sitrah Island with the east coast of Bahrain. Nabih Salih is a small island to the north of Sitrah; Jiddah, a penal settlement, is a small rocky islet off the west coast of the main island. Islands without significant human populations include Umm-Na'san (Umm an Nasan) to the north-west and the Hawar Archipelago (16 islands) about 16 km to the south-east near Qatar (Nurun Nabi, 1976). Inshore waters are generally shallow and the intertidal zone is 3000 m or more in width in several places. The islands lie in a particularly enclosed part of the Gulf, where water exchange is restricted by the Qatar Peninsula, Saudi Arabian mainland and by the barrier of reefs extending from Bahrain itself. The Gulfs of Bahrain and Salwah are mostly less than 10 m deep and temperature extremes and salinities, which are commonly over 50 ppt and up to 55 ppt at the southern end of the island, exert strong controls on the marine biota. In addition, much of the substrate is muddy or seagrass dominated which impairs coral reef development (Basson *et al.*, 1977; IUCN/UNEP, 1985).

Coral fringes occur around the north and east coast of Bahrain and off Al Muharraq and Sitrah Islands. They have very gentle gradients and descend to only about 4-6 m. Further offshore to the north and east there are several large platform reefs and various small patch reefs, which may have reef slopes extending to 10 m depth but rarely more. About ten reefs have been studied; all have very gentle seaward slopes with friable substrate, poorly attached corals and have reef flats which are largely devoid of corals. In most cases these structures are probably not actively accreting but are eroded limestone mounds supporting variable amounts of corals (Sheppard, 1985). The opinion that no reef growth is occurring is supported by the existence of almost identical structures further south which currently support no corals at all due to high salinity. On some reefs, corals cover less than 1% of the slopes and flats. Corals are not common below 10 m except on the north slope of Fasht Adhm where hard substrate at 15 m may be encountered. On muds deeper than 15 m, the ahermatypic coral *Heterocyathus* is common (1-5 colonies per sq. m). Reefs are also found off Askar. The largest reefs are Fasht Adhm off the north-east coast (*see separate account*) and Fasht al Jarim in the north.

In the south there are some small mounds of coral framework extending to 3 m depth, mostly created by *Porites nodifera* which tolerates salinity of up to 50 ppt. However, most of the substantial, shallow limestone platforms in the south support no corals at all but are colonized instead by *Sargassum* and other algae. A patch reef formed principally of the bivalve *Spondylus* has also been found. In most areas deeper than 5 m, soft substrates and seagrasses dominate.

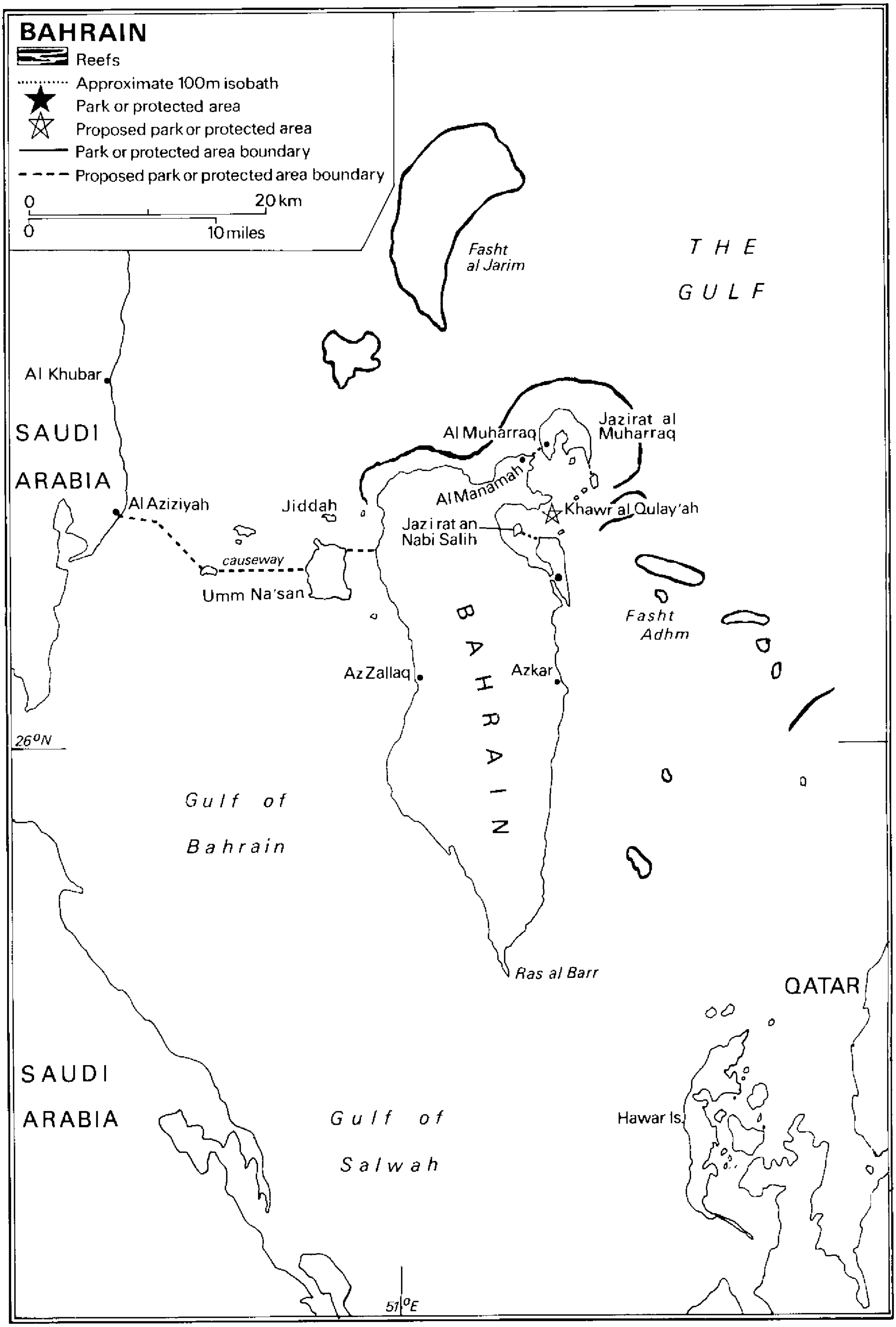
Thirty-one coral species in 19 genera have been reported (Sheppard, 1985) and these may occur in up to five assemblages as discerned by cluster analysis. *Acropora* cf *valenciennesi* dominates in one of these, providing cover of over 80% over large areas at 2-5 m depth on Fasht Adhm and other smaller northern reefs. *Porites compressa* co-dominates between 5 and 10 m depth at which depth diversity is greatest. *Porites nodifera* constructs substantial framework in higher salinity areas, and in these areas diversity is poor. Only the latter assemblage has been found off southern Bahrain and the Hawar Archipelago. The highest salinity in which corals have been recorded is 50 ppt, the three surviving species being *Porites nodifera, Cyphastrea microphthalma* and *Siderastrea savignyana*.

Detailed surveys of all critical habitats were carried out in 1985 on the intertidal and sublittoral areas around the major islands of the Bahrain and Hawar Archipelagos including the largest reef Fasht Adhm (Barratt and Ormond, 1985; Jones, 1985; Price, 1985; Sheppard, 1985). The west coast at the location of the causeway to Saudi Arabi, as well as one part (Askar) of the east coast, have also been examined (Price *et al.*, 1983; Vousden and Price, 1985). Bathymetric mapping and oceanographic modelling have been carried out by the Danish Hydraulic Institute and Wimpol Ltd.

The islands are of international importance on account of a small colony of breeding Sooty Falcon *Falco concolor* and a large proportion of the world population of Socotra Cormorants *Phalacrocorax nigrogularis*. The flamingo *Phoenicopterus ruber* is present throughout the year, and the Osprey *Pandion haliaetus* breeds there (Hill and Webb, 1983). Gallagher *et al.* (1984) describe the current status of seabird populations; there are breeding colonies of four species of terns *Sterna* spp. Up to 700 Dugongs *Dugong dugon* have recently been seen grazing on the seagrass between the Bahrain mainland and Hawar. The Green Turtle, Hawksbill, Leatherback and Loggerhead (*Chelonia mydas, Eretmochelys imbricata, Dermochelys coriacea* and *Caretta caretta*) occur and the former may breed in the Hawar Archipelago (Price *et al.*, 1983). Marine molluscs are described by Smythe (1974?). There is a patchy remnant distribution of mangroves, the main stand being near Sanad (Price *et al.*, 1983). The Bahrain Natural History Society conducts fauna and flora survey and publishes *Wildlife in Bahrain*.

### Reef Resources

Fishing, prawnfishing and pearling have traditionally played a major role in the economy of Bahrain although the latter is not pursued at present. There is an important artisanal fishery (Price *et al.*, 1983; Sergeant, 1968), fishing effort for rabbitfish (Siganidae) and grouper (Serranidae) having increased in recent years (Morgan, 1985). Wire traps or "gargoor" are mainly used in coral areas. *Siganus canaliculatus* is the most common species of rabbitfish taken; the second most important commercial species is probably the grouper *Epinephelus*


BAHRAIN
Reefs
Approximate 100m isobath
Park or protected area
Proposed park or protected area
Park or protected area boundary
Proposed park or protected area boundary
0
20 km
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Fasht
al Jarim
THE
GULF
Al Khubar
SAUDI
ARABIA
Al Muharraq
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tauvina. Trends in the fishing industry are described in Price *et al.* (1983). The beaches and shores are used regularly by the local people for recreation, particularly in the northern part of the islands (Nurun Nabi, 1976). Recreational use of the reefs is small but Fasht Adhm is popular (*see separate account*).

**Disturbances and Deficiencies**

High numbers (greater than 250 in 15 sq. m) of sea urchins *Echinometra mathaei* have been found on some reefs and may have caused damage (Price *et al.*, 1983). A causeway from Bahrain to south of Al Aziziyah on the Saudi Arabian coast has recently been built (Price *et al.*, 1983; Vousden and Price, 1985). To date, it appears to have had little impact on the marine environment but sedimentation and salinity may increase in this area. There are no coral reefs which would be immediately affected, but the situation will require monitoring. There is infilling in some areas around Al Muharraq, the Sitrah Bay area, the causeway area and south of the causeway on the west coast. Extensive dredging and associated sedimentation has occurred around the north-east of Bahrain, and may have caused a paucity of benthic flora and fauna in some areas; in particular the north-western part of Fasht Adhm (*see separate account*). Such activities may also be responsible for the decline in fishery catches reported between 1979 and 1982 (Price *et al.*, 1983). Problems on Fasht Adhm are described in the following account. Problems related to infilling and reclamation are severe in many areas and are discussed by Nurun Nabi (1976). There are plans to undertake construction on some of the reefs in the shallow sublittoral zones to the north and west. Many beaches in northern Bahrain are massively oiled (Jones, 1985) and potentially there is a serious threat from oil and chemical pollution (Johnson, 1983; Linden, 1982; Price *et al.*, 1983). The Hawar Archipelago is relatively undisturbed, partly because of access restrictions.

**Legislation and Management**

The Directorate of Environmental Affairs/Ministry of Health is responsible for marine and coastal environmental activities and the Department of Fisheries compiles fisheries statistics and carries out various environmental studies. Tha Bahrain Petroleum Company (BAPCO) is involved with oil spill contingency plans and marine environmental affairs (IUCN/UNEP, 1985). Bahrain has ratified the Regional Convention for Co-operation on the Protection of the Marine Environment from Pollution and is the Centre of the Gulf States' oil pollution warning network. The southern part of the main island and most subsidary islands are out of bounds except for fishermen and people with special permission which affords considerable protection. About a quarter of the west coast, including some beaches, and almost all of the north coast of Bahrain is privately owned. The Government has reserved about 125 acres (50 ha) of land in the north-west corner of Bahrain to develop as a beach for public recreation. In the early 1970s plans were being made to establish proper public beaches and recreational areas near Az Zallaq (half way down the west coast) and on Umm-Na'san (Nurun Nabi, 1976).

**Recommendations**

Recommendations for dealing with some of the problems of coastal management are given by IMO/ROPME/UNEP (1984) and Price *et al.* (1983). Areas of special value to fisheries or unique examples of a particular habitat should be protected from infilling, dredging or other developments. The damage caused by dredging should be reduced by controlling areas where it is permitted and by requiring the use of silt curtains. A zoning scheme should be developed to regulate infilling and dredging activities. Detailed mapping of critical habitats and species of economic or scientific importance and monitoring of sites subject to pollution should be carried out. Recommendations for improved management of fisheries are also given, including the suggestion that artificial reefs could be built in some areas. Environmental education, in relation to marine resources, is urgently required.

The Sitrah, Nabi, Saleh, Al Muharraq and Zida Islands region, around Khawr Qulay'ah (Khor al Qaliya) has been recommended as a Reserve as the islands are not populated and are surrounded by relatively unspoiled ecosystems (Anon., 1975). Price *et al.* (1983) recommend immediate protection for three sites but these do not include coral reefs (mangroves at Sanad, seagrass beds south-east of Bahrain and intertidal mudflats on the north and east coasts).

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## FASHT ADHM

**Geographical Location** Off the north-east coast, extending south-east from Sitrah Island; 26°-26°10'N, 50°40'-50°51'E.

**Area, Depth, Altitude** Almost 12x6 km; sea level to 15 m depth.

**Physical Features** A large bank, with scattered islands including Umm Jalid and some artificial islands.

**Reef Structure and Corals** The highest density of coral is found on the northern face of the reef and on the adjacent seabed sloping to 10-15 m depth. There are three distinct areas of dense coral cover (over 50%), the largest extending more or less in front of the centre of the north face, the second running as a narrow band along the face to the east and a third running out to the eastern wing of the Fasht. The shallower areas are dominated by dense, often monospecific stands of branching *Acropora* with up to 30% dead coral in some areas and coral rubble in others. The slope drops at an angle of 25-45° until 3-4 m depth, beyond which it slopes more gently, with a more diverse coral community. At 4-6 m depth, *Porites* is dominant, forming large columnar mounds, separated by other corals particularly *Platygyra lamellina, Cyphastrea microphthalma* and *Favia* sp. At greater depth, there is a more even mix of species. A total of 11-12 species of coral was recorded. Fish diversity was greatest in these high coral diversity areas, including commercial species.

Areas of less dense coral cover (10-50%) are found bordering the dense areas on the northern side of Fasht Adhm; less dense coral cover also occurs to the east, and on the reef top to the west. *Acropora* and *Porites* are dominant, as in the denser areas. Coral cover of less than 10% is found in other areas on the north face, and also in the lee of the reef, on reef patches in very sedimentary conditions and on the western end of the reef flat. In these areas, 6 species have been recorded and *Porites* sp., *Acropora* and *Platygyra lamellina* are dominant. Much of the coral on the western end of the Fasht has the appearance of being relatively new; the amount of coral may have increased as a result of the dredging of the boat channel through the western neck of the Fasht, causing an increased speed of water movement (Barratt and Ormond, 1985).

**Noteworthy Fauna and Flora** No information.

**Scientific Importance and Research** Surveyed by Barratt and Ormond (1985).

**Economic Value and Social Benefits** Areas on Fasht Adhm, particularly with slightly reduced coral cover, are important for fishing, "gargoor" and "haddra" traps being used. Fasht Adhm is used for fishing, swimming, snorkelling and picnicking on the islands by local people and expatriates. SCUBA diving for recreation or tourism is very limited but the deeper coral sites are occasionally visited (Barratt and Ormond, 1985).

**Disturbance or Deficiencies** Areas with reduced coral cover have been found on Fasht Adhm which may be partly due to increased sedimentation as a result of human activities. From aerial photographs, it appears that several large fronts of sediment are moving along the northern face of the reef from west to east, possibly caused by the use of this area for sand for reclamation and development. Some damage may be caused by the observed high density of the sea urchin *Echinometra mathaei* which is perhaps a result of the recent intensification of fishing for commercial reef species. This may have caused a depletion of pufferfish (Tetraodontidae) and triggerfish (Balistidae), known predators of the urchins (Barrat and Ormond, 1985; Price *et al.*, 1983).

Some of the observed broken coral may be due to anchor damage by fishing and pleasure boats. Oil pollution is a potential threat, high oil hydrocarbon levels having been recorded in sediment samples from Askar. Small spills, from local sources and other parts of the Gulf have come ashore on the Bahrain coast (Barratt and Ormond, 1985).

**Legal Protection** None.

**Management** None.

**Recommendations** Barratt and Ormond (1985) recommend that in any development of Fasht Adhm, the areas of high coral cover should if possible be preserved on account of their relatively high productivity and moderately high numbers of commercial fish species. It is recommended that no further dredging for sand should take place in areas where it would affect the dense coral cover on the north of the reef. Permanent moorings for pleasure boats could be placed in popular areas.

# BURMA

## INTRODUCTION

### General Description

The Burma coastline commences at about 21°N, just south of the River Ganges delta and extends to 10°N, at the Isthmus of Kra. The coastal morphology and the bathymetry of the Bay of Bengal result in mainly soft substrates off the mainland shore overlain by shallow water which is diluted and made extremely turbid by several major rivers. In the first 500 km, rivers draining the Chin Hills and the Irrawaddy discharge into the sea. The latter is notable for its extremely high sedimentation and for the rate of shoreline progradation which may exceed 60 m per year (Stembridge, 1982). South of this delta is the Gulf of Martaban which is extensive, muddy and shallow, receiving massive amounts of freshwater and sediment. As a result of this regime, extensive mangrove stands characterize most of the mainland shore. Where more open conditions prevail, sand dunes are present, colonized by dune vegetation and *Casuarina* (Macintosh, 1982). From the north the 200 m contour moves towards shore in a southerly direction, but south of the Irrawaddy it does not approach closer than about 200 km.

Off shore there are several groups of islands. The main group is the Mergui Archipelago, which lies in the south from about 13°N to the southern international border at 10°N, off the relatively narrow Malay Peninsula which has few large rivers. Although the islands all lie within 100 km of shore, they are sufficiently far from river deltas to experience clearer water conditions. The archipelago consists of over 800 islands ranging in size from King Island near Mergui town (170 sq. mi. (440 sq. km)) to small rocky islets. The islands are the higher portions of submerged ridges which appear to lie on four distinct tectonic lines (Chhibber, 1927). The outermost line, up to 90 mi (145 km) from the mainland, includes the islands of Cabusa, Tenasserim, Baileys, Prinseps, Sergeant and Hayes. Landwards of this lies a line including the islands near Moulmein, and the islands of Moscos, Elphinstone, Ross, Benticks, Maria, Clara and Loughborough, ending near the Sayer (Similan) Islands in Thai waters. A third line starts at Tavoy Point and continues southwards including Tavoy, King, Domel, Lampi and St Matthews (FAO, 1982). Another group lies off north Burma, between Akyab and the Irrawaddy, including Cheduba Island. Several islands, including Great and Little Coco and Preparis, lie near the Andaman Islands. The archipelagos remain almost completely unstudied (Macintosh, 1982).

Annual rainfall in Burma exceeds 3000 mm and results in a surface salinity of less than 33 ppt throughout the year (Couper, 1983). There are strong seasonal changes. The south-west monsoon is active in the Bay of Bengal from about May to October when rainfall is heavy, cyclones are not uncommon and winds and surface currents are northerly. For the rest of the year, rainfall is much less and winds and surface currents are southerly and weaker. Surface temperatures remain between 25° and 30°C all year. Tides are semi-diurnal and tidal range is high (4-6 m) along much of the coast.

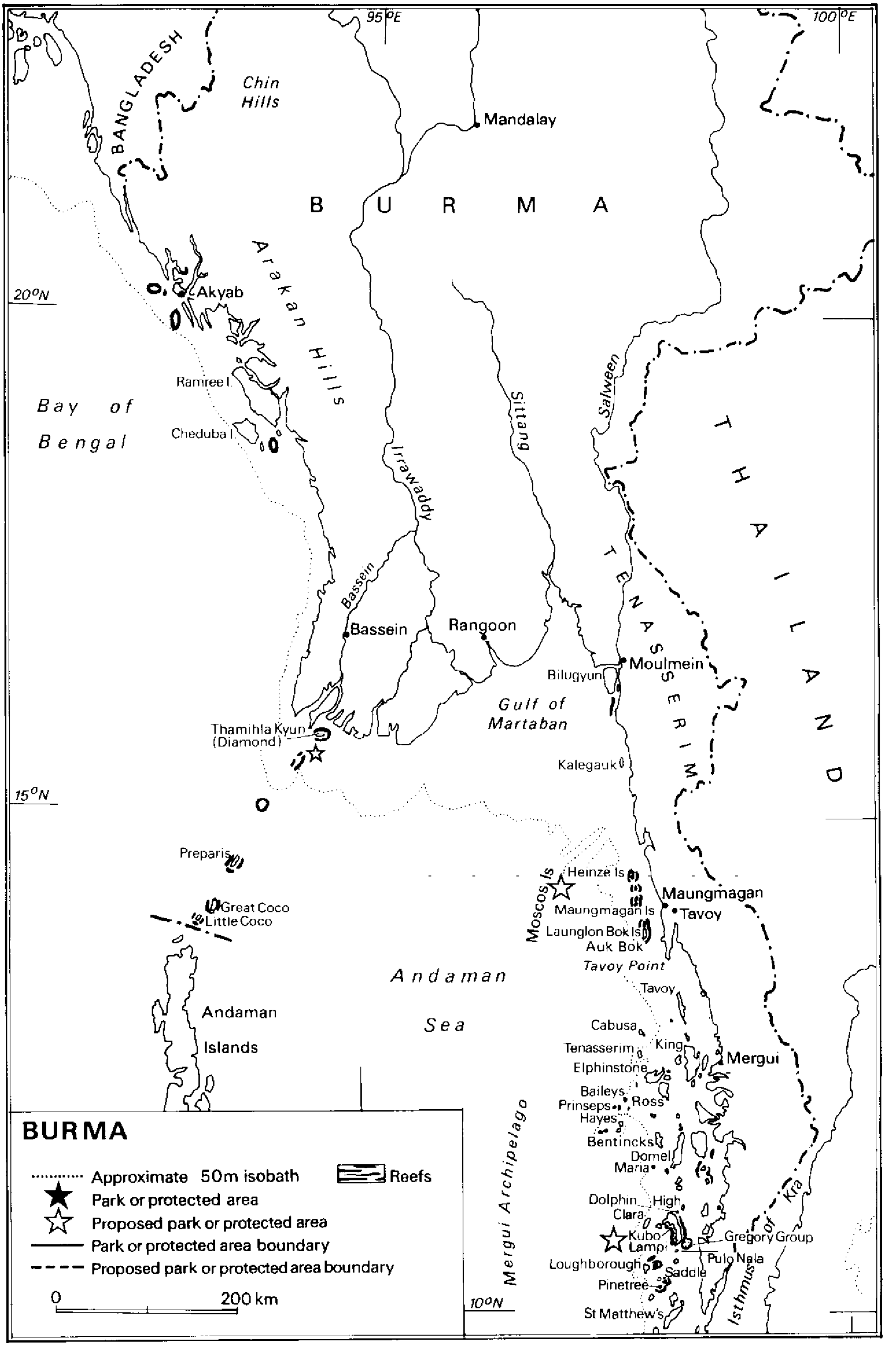
The main reef areas lie in the Mergui Archipelago (Duncan, 1899; Harrison and Poole, 1909). There are no data on the ecology of these reefs but 65 species in 31 genera have been described suggesting a moderate diversity. A more recent study recorded 61 species in 32 genera of hermatypic corals and four species in three genera of ahermatypes, collecting having been carried out at Dolphin I., Moscos Is, Lampi Is (Lanbi Kyun), Saddle I., Succor I., Pinetree I. and High I. (Kyi, 1985). It may be assumed, from the brief early descriptions and by inference from the better known islands of adjacent Thailand, that coral reef development in Mergui is appreciable. Rosen (1971) predicts that perhaps 43 or 44 coral genera may eventually be found there.

The small amount of data available for the Moscos and Lampi Islands are given in the following accounts. For the two other island groups there is no detailed information on the presence or nature of coral reefs although charts show reefs around Akyab and the islands north of the Andamans. It is unlikely that the northern group supports much reef development as, like the mainland, it is affected by river discharge, but the island group north of the Andamans is much further off shore and may support reefs as extensive as those of the Andamans themselves (Molengraaff, 1930; Tranter, 1974). There are no known coral reefs along the 2000 km mainland coast, but it has been reported that corals are found near the mouth of the Bassein River, around the island of Thamihla Kyun or Diamond Island, which is 1 sq. km in area (White, 1983); charts show reefs south of Thamihla Kyun (*see map*).

At least four marine turtle species occur in Burmese waters and possibly five (Blower, 1985). Although the Leatherback *Dermochelys coriacea* has always been rare, populations of Green Turtle *Chelonia mydas*, Olive Ridley *Lepidochelys olivacea* (both formerly abundant) and Hawksbill Turtle *Eretmochelys imbricata* appear to have declined severely since the turn of the century. Thamihla Kyun was one important nesting site for Green and Olive Ridley with over 1.5 million eggs of both species being collected annually. The Green Turtle population has decreased by around 90% since the turn of the century and, despite some protection, eggs are still collected under licence. The Irrawaddy Delta still supports an important population of the endangered Estuarine Crocodile *Crocodylus porosus*, but the formerly large population of River Terrapin *Batagur baska* (an endangered species that migrates downriver to coastal and estuarine beaches to nest) has declined to possible extinction (Groombridge, 1982; Salter, 1983). The Dugong *Dugong dugon* is now very rare (Blower, 1985).

### Reef Resources

The southern Burmese, in southern Tenasserim, and in particular the Salon or sea-gypsies, depend partly on coastal and coral reef fisheries and other marine resources such as shells, mother-of-pearl and bêche-de-mer for their living (Blower, 1985; FAO, 1982).



95°E
100°E
BANGLADESH
Chin Hills
Mandalay
B U R M A
Arakan Hills
20°N
Akyab
Ramree I.
Bay of Bengal
Cheduba I.
Irrawaddy
Sittang
Salween
THAILAND
TENASSERIM
Bassein
Bassein
Rangoon
Moulmein
Bilugyun
Gulf of Martaban
Thamihla Kyun (Diamond)
Kalegauk
15°N
Preparis
Moscos Is
Heinze Is
Maungmagan
Maungmagan Is
Tavoy
Launglon Bok Is
Auk Bok
Tavoy Point
Great Coco
Little Coco
Andaman Sea
Andaman Islands
Tavoy
Cabusa
Tenasserim
King
Mergui
Elphinstone
Baileys
Prinseps
Ross
Hayes
Bentincks
Domel
Maria
Mergui Archipelago
Dolphin
High
Clara
Kubo
Lamp
Gregory Group
Loughborough
Pulo Nala
Saddle
Isthmus of Kra
Pinetree
St Matthew's
10°N
BURMA
Approximate 50m isobath
Reefs
Park or protected area
Proposed park or protected area
Park or protected area boundary
Proposed park or protected area boundary
0
200 km

There is little marine-related tourism in Burma at present, although Maungmagan, with its fine beach, small bungalows and restaurants and easy accessibility, is popular with local holiday makers. It has considerable potential as a tourist resort from which visits could be made to the reefs in the Mergui Archipelago (FAO, 1982).

**Disturbances and Deficiencies**

The reefs are probably virtually undisturbed.

**Legislation and Management**

The Forest Department is legally responsible for nature conservation, including existing wildlife and game sanctuaries, under the 1902 Burma Forest Act and the 1936 Burma Wildlife Protection Act. Neither of these acts provides for the establishment of marine protected areas. The Working People's Settlement Board, concerned mainly with management of State Agricultural Farms, has been given responsibility for the development of proposed national parks, nature reserves and recreation areas but it lacks the necessary authority for law enforcement under existing legislation (FAO, 1985). The only coastal protected areas are Thamihla Kyun, designated as a Wildlife Sanctuary in 1970, and Moscos Island Sanctuary (*see separate account*); neither specifically protect the marine environment.

**Recommendations**

In 1980, the Government requested technical assistance from UNDP/FAO in developing a conservation programme for the country. This resulted in a number of recommendations including the establishment of part of the Mergui Archipelago, centred on Lampi Island, as a Marine National Park (*see separate account*). The administrative and legal framework for the development of a conservation programme is currently inadequate, although a number of recommendations for its improvement have been made (FAO, 1985). The establishment of Thamihla Kyun, Kadonly Kyun (a small island further east) and South Moscos as marine reserves is considered a priority in the Corbett Action Plan (Thorsell, 1985).

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## LAMPI PROPOSED MARINE NATIONAL PARK

**Geographical Location** Mergui Archipelago, about 12 miles (19.3 km) from the mainland, off southern Tenasserim; 10°51'N, 98°10'E.

**Area, Depth, Altitude** Lampi is about 48.3 km long and 6 km wide (65 sq. mi. (168 sq. km)); the proposed National Park boundary encircles a number of associated islands and intervening sea, covering a total area of

1500 sq. mi. (3885 sq. km). Max. depth between islands is 24 m; max. alt. 465 m.

**Land Tenure** No information.

**Physical Features** The main island, Lampi, is aligned north-south, and its terrain is hilly. Much of the coast is rocky, although there are a number of sandy beaches, bays and inlets. Deeply penetrating estuaries occur along the west coast. Freshwater supply is relatively plentiful; many small streams are seasonal but the Zon Chaung (Sungai Afun) is perennial. The northern part of the island curves strongly to the west, forming a large bay in which Kubo Island is situated. Associated islands, which are all considerably smaller than Lampi, include Wa-Ale Kyun and Kanzagyi to the north-west, Pulo Nala to the south and the Gregory group to the south-east. Over 30 other small islets are included in the proposed designation. The geology of the area is described by Chhibber (1927). The climate is monsoonal with little or no rain during the cold season from December to February. Mean annual rainfall at Kawthaung (17 km to the south) is 3964 mm, the wettest period being May to September. Prevailing winds during the May to September monsoon are from the west and south-west; during the rest of the year they may be easterly due to the influence of the Gulf of Thailand across the narrow Kra Isthmus. Violent squalls are common at the beginning and end of the monsoon (FAO, 1982).

**Reef Structure and Corals** Several of the small islands, especially in the Gregory group, have fine coral reefs (FAO, 1982) and there are some coral formations along parts of the coast of Lampi although these are less well developed. Corals from Lampi are described by Kyi (1985). A well-developed coral reef occurs on the west side of Pulo Myang in the Gregory group with a drop-off to about 10 m. Moderately good coral was also found off the north-west coast of Kubo Island. Some coral formations were found at Kanzagyi Island and in the Ma Khone Galet, but species diversity was lower. It is to be expected that extensive reefs will be found elsewhere around Lampi • ıd adjacent islands (FAO, 1982).

**Noteworthy Fauna and Flora** Lampi and some of the other islands are almost completely covered with evergreen forest which shows little sign of disturbance. There are undisturbed mangroves along the river estuaries on the west coast; elsewhere on the coast are fine examples of coral sand beaches with associated *Casuarina, Dillenia* and *Calophyllum* canes and palms. An endemic subspecies of mouse deer *Tragulus javanicus lampensis*, the Crab-eating Macaque *Macaca fuciphaga*, a langur *Presbytis* sp. and oriental small-clawed otters *Aonyx (Amblonyx) cinerea* exist. Further details of the terrestrial flora and fauna are given in FAO (1982) and summarized by IUCN (in prep.). Limited numbers of turtles may nest on the islands. Dolphins and dugong may occur in the surrounding water (FAO, 1982).

**Scientific Importance and Research** There has been no research on the reefs although Kyi (1985) has described corals collected at Lampi.

**Economic Value and Social Benefits** This is regarded as an outstanding natural area which has unusual potential for both tourism and conservation. There are fine beaches, safe anchorages for boats at both Lampi and Loughborough and a suitable site for an airstrip on Lampi. At present the threat of Thai pirates in this area curbs tourist potential. There are no permanent settlements apart from a small fishing village on Pulo Nala, about 1.6 km south of Lampi, which is used by fishermen. Nomadic people, the Salon, from the outer islands, establish temporary camps in the monsoon period to hunt and fish, but do no serious damage (FAO, 1982).

**Disturbance or Deficiencies** The islands are comparatively undisturbed, but turtle eggs are collected (FAO, 1982).

**Legal Protection** The legal status of the land is Unclassed Forest (FAO, 1982).

**Management** None.

**Recommendations** One of the larger islands and several smaller ones are recommended as a Marine National Park, possibly with interim status as a Reserved Forest and Wildlife Sanctuary. The provision of a small staff, located on Lampi, with a boat to guard against encroachment is recommended, and a more detailed survey should be undertaken, including the reefs, prior to preparation of a master plan. The area is considered one of the highest priorities for development within the proposed protected area system (FAO, 1983 and 1985). Suitable sites for Park headquarters and other facilities would appear to exist near the southern end of Lampi (FAO, 1983). Pakchan, an area of 1454 sq. km on the mainland directly opposite, has been proposed as a Nature Reserve and could be managed as an adjunct to Lampi; it is important for its moist evergreen forests (Blower, 1985; FAO, 1982 and 1983).

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## MOSCOS ISLANDS WILDLIFE SANCTUARY AND PROPOSED NATIONAL PARK

**Geographical Location** Northernmost islands of the Mergui Archipelago, 12-18 mi. (19.3-29 km) from the coast of mainland Tenasserim in the Andaman Sea; 13°47'-14°23'N, 97°46'-97°57'E (FAO, 1982).

**Area, Depth, Altitude** 4924 ha; South Moscos group covers approximately 9 sq. mi. (23.3 sq. km); the largest island is Auk Bok in South Moscos which is 6 x 1.5 miles (9.6 x 2.4 km); max. altitude 555 m (Heinze Island in North Moscos); average depth between islands is 24 m; maximum depth 40 m.

**Physical Features** Three groups of small islands (North, Middle and South Moscos, also known respectively as Heinze, Maungmagan and Launglon Bok), comprise the exposed summits of an otherwise submerged ridge. The islands are hilly, generally rising steeply from a rocky shoreline. Chhibber (1927) describes the geology of the region. The climate is monsoonal with little or no rain during the cold season from December to February. Mean annual rainfall at Tavoy (13 km inland) is 5451 mm, the wettest months being May to October. Prevailing winds during the monsoon (May-September) are from the west and south-west, and during the rest of the year from the north-east. Violent squalls are common at the beginning and end of the monsoon (FAO, 1982).

**Reef Structure and Corals** Extensive coral formations have been found at Thé Byin Aw and Taungnat Aw on Auk Bok (South Moscos) and some less well developed coral communities at Ohnbin Aw on the south-west coast of the same island. At Thé Byin Aw there are extensive reef flats, which are emergent at springtides, and a 15-20 ft (4.6-6.0 m) drop-off. The reef is reportedly diverse but subject to turbid water conditions. At Ohu Bin Aw there is a poor covering of *Millepora* sp. Extensive reef development is found at Nat Taung Aw, a long narrow bay, as well as large isolated coral heads at the entrance of the bay. *Acropora hyacinthus* was abundant (FAO, 1982). Coral communities have also been found at Launglon Bok and Maungmagan. Corals collected in the Moscos Islands are described in Kyi (1985).

**Noteworthy Fauna and Flora** Climax evergreen forest is relatively luxuriant and is described in FAO (1982) and summarized by IUCN (in prep.). There is a diverse bird fauna but the terrestrial mammal fauna is not particularly diverse. Further details are given in FAO (1982) and a summary is given in IUCN (in prep.). Green Turtles *Chelonia mydas* are known to nest on a beach at Auk Bok but there may be other unconfirmed sites; turtle nesting was widespread in the islands in the 1930s (FAO, 1982). Sea birds are said to be relatively scarce although the White-bellied Sea Eagle *Haliaeetus leucogaster* and Reef Egret *Egretta sacra* are present. Cave dwelling Edible-nest Swiftlets *Aerodramus fuciphaga* are found on Hgnettaik Kyun Islet in South Moscos and on Cradle Rocks in Middle Moscos (FAO, 1982).

**Scientific Importance and Research** Apart from the work by Kyi (1985), no study of the reefs has been carried out, although a brief description is given in FAO (1982).

**Economic Value and Social Benefits** South Moscos is regarded as having some recreational value as it is within easy reach of Maungmagan and Tavoy. There is some fishing especially by non-resident fishermen in the dry season. The collection of edible nests of swiftlets is a major activity. There are no facilities for visitors and the Sanctuary does not attract tourists. However, there is considerable potential for tourism due to the islands' proximity to Maungmagan and Tavoy (FAO, 1982).

**Disturbance or Deficiencies** Some illegal logging and the collection of forest produce occurs. Numbers of turtles are apparently declining steadily. Collection of turtle eggs is supposedly under licence from the Forest Department but the system is much abused; about 39 000 eggs were collected annually from South and Middle Moscos between 1978 and 1982, 60 000 having been taken in 1939 (FAO, 1982).

**Legal Protection** Originally declared as a Game Preserve on 13.5.24 under Rule 5a of the Burma Game Rules 1917. Subsequently reconstituted as a Game Sanctuary under Forest Department Notification No. 241 on 29.9.27 (FAO, 1982). The islands are protected by the 1936 Burma Wildlife Protection Act which prohibits hunting and disturbance to wildlife within designated sanctuaries.

**Management** Administered by the Tavoy Forest Division, Tavoy. Turtle eggs and the nests of the Edible Nest Swiftlet are collected under permits from the Forest Department.

**Recommendations** The three islands of South Moscos and associated islets have been recommended as a Marine National Park because of their easy accessibility from Tavoy and good recreational potential. Limited accommodation could be provided on Auk Bok and boat transport from either Maungmagan or Tavoy. Middle Moscos should retain its status as a Wildlife Sanctuary or be upgraded to a nature reserve. North Moscos should be excised from the Sanctuary and revert to unclassed so that the islands can be freely used by local fishermen. It is recommended that no further permits should be issued for the collection of turtle eggs and that a marine survey should be undertaken as part of the preparation of a master plan for the proposed park (FAO, 1982).

# CHAGOS

## INTRODUCTION

### General Description

The Chagos Archipelago, previously a dependency of Mauritius, is also known as the British Indian Ocean Territory and is administered from London, with a British Representative in Diego Garcia. It is centred at 6°S, 72°E and lies on the southernmost and oldest part of the Chagos-Laccadive Ridge, in the geographical centre of the tropical Indian Ocean.

The archipelago is a limestone cap, a few hundred metres to a few kilometres thick, resting on volcanic rock (Francis and Shor 1966). There are five atolls, with two areas of raised reef (Bellamy, 1979; Sheppard, 1980a and 1981a). The central feature is the Great Chagos Bank, probably the world's largest atoll in terms of area, which is mostly submerged but has eight islands on its western and northern rim, including Nelson, Three Brothers, Eagle and Danger. It is surrounded by the smaller atolls: Peros Banhos and Salomon to the north and Egmont (the Six Islands) and Diego Garcia to the south. Several submerged reefs, some of which are atoll-like in cross section, lie among the atolls with a total area exceeding that of the islanded atolls. Submerged structures such as these are one of the most notable features of the central Indian Ocean. Their extent in Chagos is such that in the Pleistocene low stand of the sea, about 13 000 sq. km more land was probably exposed than is the case today. The total area of shallow water is about 21 000 sq. km.

From October to April, winds are light or moderate and generally from the north-west; for the rest of the year, the south-east trades blow strongly. The area is not subject to cyclones although severe storms are sometimes experienced, especially in Diego Garcia. Rainfall is strongly seasonal, with most falling between October and April. Chagos is the wettest group of atolls in the Indian Ocean, the wettest of which is Peros Banhos (3999 mm per annum) and the driest of which is Diego Garcia. The Chagos Bank is affected by infrequent seismic tremors. Darwin (1842) recorded a tremor which destroyed an island in Peros Banhos. During scientific visits in the 1970s two or three tremors were felt (Bellamy, 1979). Spring tidal ranges are about 1.2 m with neap ranges of about 0.2 m (Pugh and Rayner, 1981). Low spring tides usually occur at 09.00 and 21.00 hours, but their duration until nearly noon, several times each year, causes the reef flats to be exposed to 0.3 m during periods of strong sun.

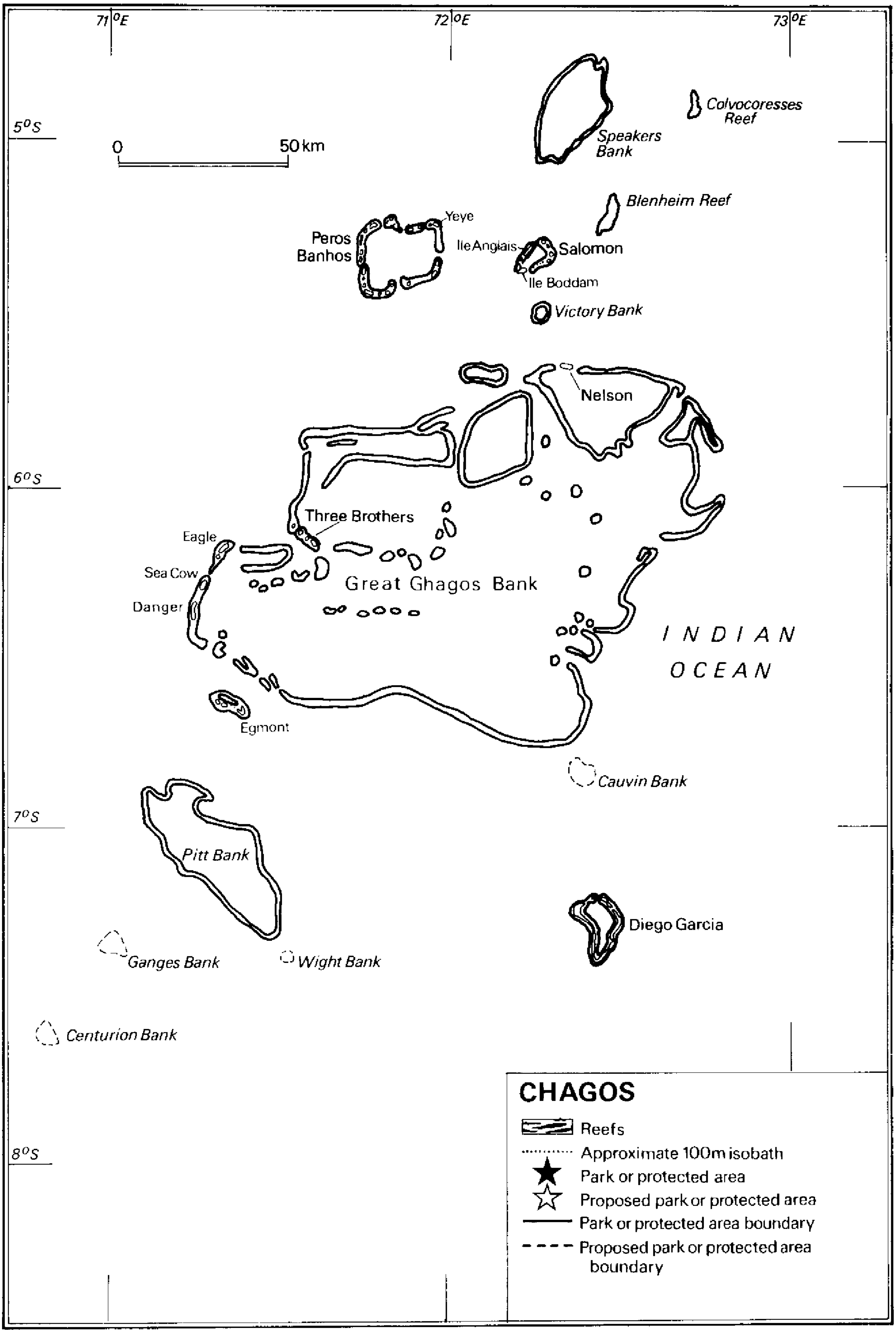
The Chagos reefs were mapped in detail by Moresby in 1837 and the more recent Joint Services Expedition carried out ground truthing of Landsat images (Sheppard, 1981a). Darwin (1842) discussed the atolls extensively in his exposition on coral reef formation, as did Bourne (1888) when he argued against reef formation by subsidence. Gardiner (1936) provided descriptions of several parts of Chagos which he visited in 1905 during the Percy Sladen Expedition. Early scientific expeditions are described by Stoddart (1971b). Few visits were then undertaken until Stoddart and Taylor (1971) visited Diego Garcia and made collections from the island and reef flat. A U.K. Joint Services Expedition visited Egmont Atoll in 1972, and a second Joint Services Expedition visited a number of areas on the western rim of the Archipelago in 1975 (Bellamy *et al.*, 1975). The first detailed ecological reef studies were made in 1978/79 when all the uninhabited atolls and several submerged banks were examined in the course of a U.K. Joint Services Expedition, Chagos Research Project (Bellamy, 1979; Sheppard, 1981a). Frazier (1977) provides a general description of the atolls. The islands which used to be inhabited such as Nelson, and those on Peros Banhos, Salomon and Diego Garcia, are most well known as they have been visited most often.

All atolls and submerged banks appear to be actively growing reefs. Chagos contains the largest expanse of totally undisturbed reefs in the Indian Ocean, as well as some of the richest. About 200 species of scleractinian corals have been recorded (Sheppard, 1981b); Stoddart (1984) lists 67 genera of which 60 are hermatypic. The coral fauna is also discussed by Dinesen (1977) and Rosen (1971). One abundant brain coral is endemic; *Ctenella chagius* occurs throughout the archipelago and is the only Indo-Pacific member of its family (Sheppard *et al.*, 1984). A total of 384 species of molluscs have been recorded (Sheppard, 1984) and the Conidae are described by Kohn (1968) and Kohn and Robertson (1966). For corals and molluscs, diversity may be higher on Chagos than on any other atoll group in the Indian Ocean, despite its remoteness, diversity is not particularly high for fish and algae (Emery and Winterbottom, 1979; Russell, 1981); the low fish diversity may be partly due to the scarcity of marine algae (Sheppard, 1981a). Seagrasses are abundant only on some of the northern submerged atolls and in the lagoon of Diego Garcia (Drew, 1980). The islands are important breeding grounds for Green Turtles *Chelonia mydas* and Hawksbill Turtles *Eretmochelys imbricata*; a 1970 survey of Peros Banhos, Salomon, Diego Garcia and Nelson Island found both species in all areas (Dutton, 1980; Frazier, 1977; Sheppard, 1980a). There are substantial populations of the Coconut Crab *Birgus latro*, whose average size is greater on islands which have been abandoned for the longest time. There are no endemic terrestrial animals.

Vegetation on all the larger islands has been disturbed by the copra industry and coconut trees dominate, although there is still a fringe of *Tournefortia* and *Scaevola*. Some islands are dominated by *Casuarina* which has replaced the hardwood trees once abundant enough to "furnish good timber" (Moresby, 1884). Other soft-wooded trees were abundant. Many smaller islands were unplanted and remain relatively undisturbed, supporting stands of original hardwood and other vegetation, and large breeding colonies of many bird species. Bellamy (1979), Bourne (1971), Feare (1984) and Loustau-Lalanne (1962), describe the seabirds of the Archipelago, thirteen species breeding there.

### Reef Resources

Following Portugese discovery in the 16th Century, the atolls, known as the Oil Islands, were farmed for coconuts or copra, coconut oil production exceeding 120 000 gallons annually (Moresby, 1884). The Chagos


71°E
72°E
73°E
5°S
6°S
7°S
8°S
0
50 km
Colvocoresses Reef
Speakers Bank
Blenheim Reef
Yeye
Peros Banhos
Ile Anglais
Salomon
Ile Boddam
Victory Bank
Nelson
Three Brothers
Eagle
Sea Cow
Danger
Great Ghagos Bank
INDIAN OCEAN
Egmont
Cauvin Bank
Pitt Bank
Diego Garcia
Ganges Bank
Wight Bank
Centurion Bank
CHAGOS
Reefs
Approximate 100m isobath
Park or protected area
Proposed park or protected area
Park or protected area boundary
Proposed park or protected area boundary

islands were also minor producers of salt fish, mainly from the demersal fishery, but this never became important because of the isolation of the archipelago. The main commercial species present is coral cod *Plectropoma* sp. (Kyushin *et al.*, 1977; Sheppard, 1981a). Handlining for shark and predatory teleost fish was carried out on Speakers and Great Chagos Banks. There is some ciguatera (Frazier, 1977). The atolls were evacuated in the early 1970s apart from Diego Garcia which is now a U.S. military base and the only inhabited atoll.

**Disturbances and Deficiencies**

The islands have been intensively modified for coconut plantations and little remains of the original terrestrial biota, although this may be returning now that they are no longer inhabited. However, the reefs are largely undisturbed although increasing disturbance can be expected to the lagoon biota of Diego Garcia (*see separate account*). Disturbance by visiting yachtsmen is probably minimal, and the local people, until they left, had a minimal impact on marine resouces (Frazier, 1977).

However, although there are few threats to the archipelago at present, apart from on Diego Garcia, the situation may change. The 1966 Treaty Agreement (Cmd 3231 of 30 December 1966) specifically provides that the whole of the Chagos Archipelago shall be available for defence purposes. Accordingly, any formal undertaking to protect the wildlife in and around the islands would lead to legal complications (Foreign and Commonwealth Office pers. comm. to C. Sheppard, 1980). Furthermore, the islands are still claimed by Mauritius.

**Legislation and Management**

At present, the inaccesibility and uninhabited nature of all parts except Diego Garcia protect the archipelago but there is no legal protection. Under Ordinance 2 of 1968 (S.I. No. 11), the B.I.O.T. Commissioner has powers to make regulations for the preservation of wildlife including any change or alteration in the environment of the species. The collection, possession and sale of Green Turtles are prohibited under this Ordinance (Frazier, 1977; Stoddart, 1971e).

**Recommendations**

Formal protection of Chagos has been recommended by Bellamy (1979) and Sheppard (1980a and 1981a) as the archipelago contains the largest expanse of undisturbed reefs in the Indian Ocean; has the highest known diversity of corals and molluscs in the Indian Ocean; and the smaller islands have very large seabird populations, original hardwood vegetation, notable Hawksbill Turtle nesting beaches and the threatened Coconut Crab. Nelson Island has been recommended as a nesting reserve for Green Turtles and frigatebirds (Fregatidae) (Frazier, 1977). The small islands off the Great Chagos Bank and northern atolls in particular are especially vulnerable and worthy of protection. Salm (1980) carried out a research project in the archipelago to define the minimum core area required for satisfactory protection of the reef. This was estimated to be at least 300 ha, if 75% of the coral genera and subgenera typical of the reef were to be found within the area. Chagos has been identified under the Corbett Action Plan for Protected Areas of the Indomalayan Realm as an area with marine conservation needs (Thorsell, 1985).

Sheppard (1981a) discusses the fisheries potential of the archipelago which is small, given the low fish diversity. If commercial exploitation were to start there would be a risk of overfishing and particular precautions would need to be taken to avoid this. There is clearly scope for much further research on all aspects of the reefs and marine environment.

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## BLENHEIM REEF

**Geographical Location** East Chagos Archipelago; 5°12'S, 72°29'E.

**Area, Depth, Altitude** 40 sq. km (but Frazier (1977) gives an area of 20 sq. km); lagoon maximum depth 17 m, average depth 6-10 m.

**Physical Features** Climatic and oceanographic conditions are similar to those of Salomon Atoll. The lagoon is exceptionally shallow and the entire rim is submerged at high tide, although about 40% of it dries at low tide.

**Reef Structure and Corals** There is limited information for Blenheim, and the following is derived from Sheppard (pers. obs., 1979). At low water, the western rim of the atoll is submerged to 1 m. It is largely planed smooth, with only occasional colonies of *Phylospongia, Millepora, Stylophora* and *Acropora*, and no *Porolithon*. The eastern rim by contrast dries at low water and emerges to over 0.5 m. It has an algal ridge on the eastern side 100 m broad, identical to those of the islanded atolls (Sheppard, 1981b), which supports a rich cover of algal nodules and has surface depressions heavily colonized by *S. pistillata, A. palifera* and *Heliopora coerulea*. At the seaward edge of the ridge, the algae constructs irregularly shaped spurs. Lagoonward of the eastern rim is a broad shelf, part bare rock colonized by *Acropora* spp., *Montastrea curta* and *Favia favus*, but mostly covered with sand. The lagoon reef slope descends gradually to a sandy floor with numerous small knolls which reach the surface. Sedimentation is high but the knolls have a high diversity of soft and scleractinian corals, and are covered at their shallowest points by *Millepora*, faviid and mussid corals.

Seaward slopes are very similar to those of the islanded atolls in terms of coral diversity and cover, the few observations of zonation indicating that similar species are involved such as *A. palifera* and *S. pistillata* in shallow areas, and *Pachyseris speciosa* and *Echinopora lamellosa* in deeper water. *Millepora* and the octocoral *H. coerulea* are dominant in the lagoon. The seaward slope profile on the eastern, emergent rim resembles that of the islanded atolls with a gentle slope down to a drop-off at about 15 m. The reef slopes descending from the permanently submerged rims differ, however, descending very gradually to at least 30 m depth.

The most exposed east and south-east sides have massive, algal ridge and spur structures indicating strong water movement. Wave-pumping forces sediment, derived from the rich hermatypic growth of the eastern seaward slope, across this rim and into the very shallow lagoon. Water also enters over the western rim and some exits through the single channel in the south of the atoll. It is likely that the largely bare rock of the western rim suffers scouring by the sediment-laden water from the lagoon which flows over it at most states of the tide.

**Noteworthy Fauna and Flora** No information.

**Scientific Importance and Research** The algal ridge on the eastern rim is the broadest known in Chagos and is remarkably substantial for the Indian Ocean. Blue coral *Heliopora coerulea* is an important component in the lagoons. The reef was visited in the course of the U.K. Joint Services Expedition of 1978/1979 (Bellamy, 1979; Sheppard, 1981a).

**Economic Value and Social Benefits** No information.

**Disturbance or Deficiencies** No information.

**Legal Protection** None.

**Management** None.

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## DIEGO GARCIA

**Geographical Location** Southernmost atoll; 55 km south of Great Chagos Bank; 7°20'S, 72°25'E.

**Area, Depth, Altitude** Total area of atoll is 170 sq. km; area of land 30 sq. km; max. alt. 7 m. Total area of lagoon 124 sq. km; maximum depth 31 m in northern basin; southern basin less than 5 m deep. The peripheral reef covers 47 sq. km.

**Physical Features** The geomorphology of Diego Garcia is described by Stoddart (1971c). About 90% of the atoll rim is continuous land which makes this an exceptionally enclosed atoll. The remaining 10% is in the north and consists of three islands separated by fairly narrow passes. No raised reef exists. The atoll rim is 0.5 km wide on average, reaching to 1 km in places, although parts of it, especially in the north-east, are very narrow but still support land. The highest points are sand drifts which form where the south-east trades meet land. Brackish barachois (tidal swamps) are found in the south of the atoll. The lagoon is relatively shallow with three basins, of which the northern is deepest, and is described by Stoddart (1971c).

Rainfall is about 2600 mm a year, and there is more seasonal variation than elsewhere in Chagos due to the greater latitude and the stronger effects of the south-east trades. The rainfall gradient in Chagos is 6 mm per km between Salomon in the north and Diego Garcia in the south (Stoddart, 1971d). Unlike the northern atolls, cyclones have been recorded. Stoddart (1971d) provides further details on wind, tides and temperature.

**Reef Structure and Corals** Reef flat corals are described by Rosen (1971), and reef slope corals by Sheppard (1980b). Only brief observations have been made of the seaward reef slopes (Sheppard, pers. obs). On the western side and southern point, coral cover and zonation are similar to that of the northern atolls. One anomaly is a belt about 5 m wide on the seaward slope at 10 m depth, which has very low coral cover. No explanation for this is available.

Seaward reef flats emerge at low spring tides and have, in common with other reef flats of Chagos, a very poor coral cover. The algal ridge is present, though less developed than on other atolls. A brief survey of the lagoon has been made (Sheppard, 1980b). Observation of many knolls confirmed Gardiner's view that coral knolls vary greatly within short distances with regard to coral cover and growth. The reason for this is not known and no particular distribution pattern was observed within the lagoon. Coral cover between knolls is sparse (less than 2% below 20 m depth) which confirms Gardiner's observation 75 years earlier. The top parts of the knolls are commonly dominated by *Acropora hyacinthus* and *A. reticulata* to within 1 m of the surface; faviid assemblages are found from a depth of 7 m to the lagoon floor. In total, diversity was similar in 1979 to that of comparable lagoonal knolls of other Chagos atolls, but coral cover was lower. In more southern parts of the lagoon where the water is shallower and the habitat very sheltered, corals become sparse, corresponding with an increase of soft substrate and relatively abundant seagrass *Thalassodendron ciliatum*.

**Noteworthy Fauna and Flora** There is a dense bed of the seagrass *Thalassodendron ciliatum* in the lagoon, one of the few to be found in Chagos (Drew, 1980). Marine algae are described by Rhyne (1971). Stoddart and Taylor (1971) provided species lists for most taxonomic groups. Taylor (1971a) described shallow water marine fauna, Clark and Taylor (1971) described echinoderms, and Taylor (1971b) described molluscs. Terrestrial flora and fauna are described in a number of papers in Stoddart and Taylor (1971) and in Sheppard (1981a). The coconut crab *Birgus latro* occurs. The Hawksbill *Eretmochelys imbricata* has been recorded in the lagoon; both Hawksbills and Green Turtles *Chelonia mydas* occurred on Diego Garcia in the last century (Dutton, 1980; Stoddart and Taylor, 1971). The island had dense vegetation in the 1930s (Gardiner, 1936). Birds are described by Bourne (1971).

**Scientific Importance and Research** Early expeditions to the atoll included the Percy Sladen Trust Expedition (Gardiner, 1936), and are described by Stoddart (1971b) and a bibliography is given in Stoddart (1971f). Results from the 1971/72 expedition are published in Stoddart and Taylor (1971).

**Economic Value and Social Benefits** The only inhabited atoll. Dried fish and turtles used to be supplied to Mauritius from Diego Garcia (Stoddart, 1971e). The U.S. military base supports a naval and air facility of a few thousand personnel.

**Disturbance or Deficiencies** Widespread and severe destruction of the lagoon may have occurred as a result of the military base (Myers, 1985) but this has not been confirmed. A survey of the lagoon early in the process of harbour construction showed much dredge damage although there was noticeable coral recolonization (Sheppard, 1979 and 1980b). Current damage to the reefs is not known. The lagoon is 90% enclosed and has very limited water exchange, so that shipping activities are potentially a major threat.

**Legal Protection** None.

**Management** In the 1870s, the manager of the plantations forbade the killing of turtles, seabirds and coconut crabs (Stoddart, 1971e). Current management is not known.

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## EGMONT ATOLL (SIX ISLANDS)

**Geographical Location** Western Chagos Archipelago; 6°40'S, 71°20'E.

**Area, Depth, Altitude** About 10 x 4 km; area 30 sq. km; the lagoon has an average depth of 10-15 m with a maximum depth of 26 m.

**Physical Features** Egmont has five islands on its southern rim, with reef flat forming most of the northern rim, through which two passes penetrate. The islands are all low islands, with no raised reefs. Oceanographic and meterological conditions are similar to those of the two northern atolls, although it is a fairly open atoll with a better water exchange than Salomon.

**Reef Structure and Corals** The structure of most of the seaward reef slopes is similar to that of other Chagos atolls. One feature appears to be unique to Egmont - in the passes, the reef slope descends normally at first to 20 m, but then rises to form a sharp ridge 3 m from the surface, before the reef finally plunges downwards. This structure is termed a "coffer dam" (Bellamy, 1979). Coral diversity follows the same pattern on seaward slopes as on the northern atolls of Chagos. The main passes were particularly rich in benthic and pelagic life, which is attributed to frequent, strong water currents and their associated water-borne food.

**Noteworthy Fauna and Flora** Bellamy (1979) describes the terrestrial fauna and flora of Egmont, particularly the birds, and the history and uses of several of the main species. Takamaka trees and Bois Mapu (*Barringtonia asiatica*) remain, particularly to seaward of coconut groves, where they were left for protection against erosion. The marine vegetation is described by Russell (1981).

**Scientific Importance and Research** As with other Chagos atolls, Egmont is very diverse and completely unspoiled. Much of the scientific information is summarized in Bellamy (1979). An early description is given in Gardiner (1936).

**Economic Value and Social Benefits** No information.

**Disturbance or Deficiencies** The reefs are unaffected by man. The islands have all been damaged by the felling of much of the native vegetation for coconut planting. Despite this, they are important for birds (Bellamy, 1979) although these have not been censused.

**Legal Protection** None.

**Management** None.

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## GREAT CHAGOS BANK

**Geographical Location** 6°S, 72°E.

**Area, Depth, Altitude** 18 000 sq. km; the eight islands total 1008 acres (408 ha). Near the islands, the atoll rim is usually less than 12 m deep; in other areas it is between 12 and 30 m deep. The lagoon floor is 80-90 m deep.

**Physical Features** The Great Chagos Bank is generally regarded as a giant atoll. Over 99% of the lagoon and rim are submerged. In the east and south in particular, the rim is several kilometers broad with many deep passes. Several of the larger structures which rise from the lagoon floor have depressions in their centres and resemble faroes. They are themselves larger than some of the atolls and submerged atolls of Chagos.

Dumb-bell-shaped Nelson Island is situated on the central part of the northern rim, while all other islands are found in two groups on the western rim: the Three Brothers and the trio Eagle, Sea Cow and Danger Islands. The islands are all low but two of the Three Brothers group have raised reefs, with vertical cliffs 4 m above high water, most notably on North Brother. On the lagoon side of Nelson Island, the shoreline is mainly horizontally stratified rock, forming miniature cliffs 1 or 2 metres high, and there is a sandy beach. Four small islands make up the Three Brothers Group; the smallest, named Resurgent, was marked as a shoal in Moresby's 1837 chart but now stands 1 m above high water. These are within 3 km of each other; the reef platform on which they lie is very irregular and has the appearance of being a large faro. Eagle, Sea Cow and Danger Islands provide the greatest land mass of the Great Chagos Bank. None contain raised reef, though Danger in particular has a shoreline composed to large extent of inclined beach rock.

**Reef Structure and Corals** On the west and north, where the rim of the atoll has been examined, the reefs have a morphology, coral diversity and zonation very similar to the smaller atolls of the Archipelago. Coral calcification (Sheppard, 1981a) proceeds at rates similar to reefs worldwide and there is no reason to support the long held view (Darwin, 1842) that the reefs of the Great Chagos Bank are submerged because they are dead or dying. The following details are taken principally from Bellamy (1979), Bellamy *et al.* (1975) and Sheppard (1981a).

Nelson Island is surrounded by a short reef flat with poor coral cover. At the edge of the seaward reef, spur construction is moderate or absent and the reef slope shelves gently to about 8 m, before descending vertically to at least 30 m. This vertical slope is extensively penetrated by fissures and caves, several metres deep and wide, and commonly interconnected with each other. Gorgonia and other cryptic fauna are abundant, testifying to a good water exchange through the cavities. Bellamy (1979) suggests that these are a result of reef slumps, possibly connected with earthquake activity. On the surface of the slope, a typical zone of leafy *Pachyseris speciosa* occurs from 20 m depth. The reef flat on the lagoon side of Nelson Island extends for 50-100 m from the shore, before descending to a level plateau at 30 m with over 80% cover of coral and soft coral. The plateau extends several hundred metres before shelving down to the full depth of the lagoon.

For at least 20 km east from Nelson Island the submerged rim is a relatively smooth structure, and its upper surface is 10-15 m deep. Hard and soft coral cover on the rim is over 70% and species and zonation are not noticeably different from that elsewhere in Chagos. Reef slope profiles are also similar.

Some of the islands in the Three Brothers Group have a typical reef flat and slope, but others, particularly North Brother, have no reef flat between the raised reef cliff shoreline and the reef slope. Middle Brother lies on the side of an annular reef, or small faro, itself like a miniature atoll with a central sandy lagoon and a pass opposite the island. To the south of Three Brothers there is one of the main passes into the Great Chagos Bank lagoon. Reef slopes are steep here, and currents are strong. The biota of the channel has a substantial growth of the ahermatypic coral *Dendrophyllia* in water as shallow as 3 m. Bellamy (1979) suggests that this is due to the strong, food-bearing currents of the pass.

To seaward of Eagle, Sea Cow and Danger Islands there are short reef flats, followed by steep descents to over 1 km. On the lagoonal side to the east there is a more gentle slope, with typical coral zonation despite the very large size of the lagoon. Large expanses of *Acropora* characterize much of the lagoon slope, particularly off Danger Island where *A.* cf *formosa* provides 80% cover over at least 100 ha. Lagoonal knolls near Eagle Island reach to within 5 m of the surface, their biota resembling that of the lagoonal reef slope of the Bank.

**Noteworthy Fauna and Flora** There are dense populations of breeding seabirds, over 50 species having been seen on and near the islands and 116 562 breeding pairs having been recorded. These include the Sooty Tern *Sterna fuscata fuscata* (26 000 breeding pairs), two noddies *Anous* spp. (90 000 pairs), two frigatebirds *Fregata* spp., (700 pairs), Audubon's *Puffinus lherminieri* and the Wedge-tailed Shearwater *P. pacificus* with 200 and 5900 pairs respectively, and three species of booby *Sula* spp. (over 7000 pairs). Most of the Chagos bird population is found on a few islands totalling about 400 acres on the Great Chagos Bank (Eagle Island being the only one with few birds) (Bellamy, 1979). Several thousand pairs of terns also nest on the northern atolls of Chagos which remain uncensused (Sheppard pers. obs.). Green Turtles *Chelonia mydas* nest on several of the islands, and the Coconut Crab *Birgus latro* is abundant on Eagle and Danger Islands. Fish, particularly vast schools of *Caranx* and sharks, are abundant around Nelson Island, especially on the rim east of the island. The islands of the Chagos Bank, particularly the Three Brothers, are an important reservoir of native Indian Ocean hardwood vegetation.

**Scientific Importance and Research** The principal importance of the reefs is that they are virtually undisturbed. The atoll was selected for discussion by Darwin (1842). The islands are especially important due to the existance of large bird populations and stands of hardwoods. Eagle Island has a peat deposit with sub-fossil pollen records of vegetation over several thousand years old; this is thought to be the only example of a peat deposit on an atoll (Bellamy, 1979).

**Economic Value and Social Benefits** Handlining for shark and predatory teleosts was carried out on the bank (Frazier, 1977).

**Disturbance or Deficiencies** Although the reefs are entirely unaffected by man, the islands have suffered some disturbance which is greater on larger islands.

**Legal Protection** None.

**Management** None.

**Recommendations** The reefs and islands of Great Chagos Bank are strongly recommended for protection (Bellamy, 1979; Sheppard, 1981a).

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## PEROS BANHOS ATOLL

**Geographical Location** Most north-westerly Chagos atoll; 5°20'S, 71°55'E.

**Area, Depth, Altitude** 463 sq. km; atoll rises steeply from over 2 km depth; max. alt. of islands about 5 m; lagoon has a maximum depth of 80 m and an approximate mean depth of 38 m.

**Physical Features** Peros Banhos is a typical, rather square-shaped atoll, with numerous islands around the rim, separated by channels which afford good water exchange (Rayner, 1983). All islands except one have sloping shores which are part sandy, part sloping beachrock, and are well vegetated with coconut, *Casuarina*, or indigenous trees. The exception is Gunner's Rock, in the south-east, which is a raised reef with sheer limestone to 4 m around most of its perimeter and is vegetated with grasses and low plants only. Peros Banhos has a mean annual rainfall of 4000 mm; further details are given in Stoddart (1971a).

Hydrology and physical and biological oceanography have been studied by Rayner (1983) and Rayner and Drew (1984). Oxygen levels are at or near saturation everywhere. Nitrogen fixation on the reefs is substantial and leads to high primary productivity in the lagoon compared with waters outside the atoll rim. Phosphate enhancement also occurs, particularly near islands and after heavy rain (Rayner and Drew, 1984) due to leaching of guano deposits. Water clarity is very high on the outer reef slopes, but is reduced to 30 m or less in the lagoon. Water temperature is 25-30°C.

**Reef Structure and Corals** Reef structure and corals are described by Sheppard (1980c, 1981b and c). On the seaward sides, reef flats extend 10 to 200 m out from the islands and are of hard pavement, with some cryptic fauna, mainly brittlestars, but few corals. Nitrogen fixing algae are fairly abundant. A classic and clear boulder zone, followed by a moat zone, exists around much of the atoll. To seaward of this, around most of the atoll, is an algal ridge with an associated spur and groove system constructed from *Porolithon*. It is best developed in the south where the algal ridge is 20 m wide with spurs over 50 m long extending to about 5 m depth. In the north, spurs of *Porolithon* are found without an associated ridge.

Seaward of the spurs, *Acropora palifera* is dominant to about 5 m and has an encrusting morphology, compared with the branching form found in less exposed sites. In the south-west, the blue coral *Heliopora coerulea* replaces *A. palifera* and provides a near total cover over at least 10 ha. Coral diversity increases rapidly from 5 m to a maximum at 20 m, where there is no evident zonation and a very heterogenous coral composition is found. On the deeper reef slope *Leptoseris* increases from 10% to 90% cover. Below 50 m, a species of *Coscinaraea* increases in abundance, though coral cover falls to below 20% and is equalled by sponges and gorgonians. Encrusting red algae were also abundant (25%) in the transects examined. At 60 m, a series of buttresses are sometimes found, reminiscent of the shallow spur and groove structures. Hermatypic growth clearly continues beyond 60 m.

Lagoonal reef flats have occasional patches of high coral cover. *Acropora, Porites* and *Pavona* are the commonest genera, all forming micro-atolls. The reef flat is again hard pavement, but with an extensive sandy covering which shifts seasonally and tidally. Where it is most exposed to the trade winds the reef flat is fringed with rudimentary algal spurs which are blocks of *Porolithon* growth similar in structure but smaller in size to the seaward spurs. As on seaward slopes, the shallowest part of the lagoonal slope below the spurs is dominated by *A. palifera*, but with a branching form, with branches orientated into the waves. Diversity increases to about 15 m depth as on seaward slopes; below 20 m depth *Lobophyllia* and *Galaxea* increase, the latter being the sole coral over large expanses of the lagoon floor. In some deep areas, *Goniopora stokesi* is dominant and expands its own coverage by the propagation of polyp balls. Lagoonal knolls are numerous with scoured upper surfaces and a very high cover of tabular *Acropora* species such as *A. cytherea* and *A. clathrata* below 5 m. Their general coral cover and zonation is similar to that of the lagoonal reef slopes. On the south of several knolls, there are unexplained pinnacles about 5 m in diameter and up to 20 m tall which may be eroded features; they support the only gorgonians found in the lagoon.

**Noteworthy Fauna and Flora** Substantial numbers of Hawksbill Turtles *Eretmochelys imbricata* nest on beaches in Peros Banhos, particularly on the island of Yeye, including the largest recorded specimens (Dutton, 1980). Coconut Crabs *Birgus latro* are abundant, but no quantitative data exists. Numerous tern species, Masked Boobies *Sula dactylatra* and Brown Boobies *S. leucogaster* nest on the atoll's smaller islands. Vegetation, echinoderms, molluscs and fish are described in Sheppard (1981a).

**Scientific Importance and Research** Peros Banhos has an exceptionally rich reef biota and reefs which are virtually pristine. The blue coral *Heliopora coerulea* is very abundant. The massive algal ridge and spurs, along the seaward side of the reef flats, and the rudimentary spurs, which are unconnected to ridges either in the lagoon or on sheltered seaward reefs, are also notable. The atoll was the base for the 1978/79 U.K. Joint Services Expedition and its sublittoral biota is extremely well documented. An early description is given by Gardiner (1936) and the atoll was visited briefly by the Yale Seychelles Expedition in 1957 (Kohn, 1964).

**Economic Value and Social Benefits** No information.

**Disturbance or Deficiencies** The reefs are undisturbed. The large islands have been severely affected by the copra industry in the past but the smaller islands are relatively undisturbed.

**Legal Protection** None.

**Management** None.

## SALOMON ATOLL

**Geographical Location** one of the two northern atolls; 5°20'S, 72°15'E.

**Area, Depth, Altitude** About 38 sq. km in area (but Frazier (1977) gives 25 sq. km); the 25 km perimeter consists of 11 km of islands and 12.5 km of reef flat. The lagoon is 24 sq. km, has an average depth of 22-27 m and a maximum depth of a little over 30 m.

**Physical Features** The islands and reef flats account for all but about 6% of the perimeter of the atoll. There is only one pass of 1.5 km wide in the north through which there is impeded water flow due to a sill at 6 m depth, causing restricted water exchange into the lagoon. Water is mainly pumped across the reef flats into the lagoon, even on ebb tides, and exits through the single channel in the north. Nitrate and phosphate is high in lagoonal waters with large concentrations accumulating in bottom waters near the sediments (Rayner, 1982; Rayner and Drew, 1984). There is a very low level of zooplankton within the lagoon compared with outside, and the lagoon contains few benthic obligate filter feeders. Water visibility is always much reduced in the lagoon. Maximum tidal range is about 1.5 m. The strongest wave action comes from the south-east during the trade winds between June and September. Rainfall averages 3750 mm per annum, with most falling between November and March (Stoddart, 1971a).

**Reef Structure and Corals** The seaward reef profile on the eastern side is similar to that of Peros Banhos, with a broad reef flat (but only moderate development of an algal ridge and spur system) and a drop-off at about 15 m depth. However, on the western side of the atoll the reef flat is very much reduced or even absent. Here, the boulder zone occurs on the beaches of the islands, and the reef slopes downward directly from the beach. The drop-off in this section is at only 4 m depth and the reef plunges steeply to over 60 m depth; landslip scars are seen on the reef surface where parts have broken away and slid down. The seaward reef slope in the vicinity of the pass is similar; from the sill at 6 m depth the face is vertical down to a depth of at least 60 m. Coral zones on all seaward slopes follow the pattern for Peros Banhos. Both forms of *Acropora palifera* are abundant in shallow water where the species provides over 50% cover on all parts of the seaward slopes between 1 and 5 m depth (Sheppard, 1980c, 1981a and b).

In the lagoon, knolls are abundant. Unlike those of Peros Banhos they reach the low water mark and are actively expanding outwards due to their high cover (over 80%) of faviids and *Millepora*. Whereas coral diversity is high on the seaward reef slopes, it is much reduced inside the lagoon, due to increased turbidity and reduced water exchange.

**Noteworthy Fauna and Flora** Fairly extensive growth of Black Coral *Antipatharia* occurs below 40 m depth in some areas of the seaward slopes. On Ile Boddam, the Coconut Crab *Birgus latro* is abundant, and some moderate-sized specimens have been observed. Several species of terns breed on the smaller islands, but the large islands support rats and fewer birds. Sheppard (1981a) provides brief descriptions of gorgonians, alcyonarians, echinoderms, molluscs, fish and terrestrial vegetation. Turtles nest on Ile Anglais.

**Scientific Importance and Research** The atoll was well studied in the late 1970s, and a relatively large body of publications on its oceanography and biology are available. An early description is given in Gardiner (1936).

**Economic Value and Social Benefits** No information.

**Disturbance or Deficiencies** The reefs are almost totally unaffected by man and, as the islands are uninhabited, are not currently threatened. The smaller islands were not planted for copra and remain relatively undisturbed, but the larger islands underwent extensive vegetation removal for the planting of coconuts. Introduced rats on some of the larger islands have reduced bird populations.

**Legal Protection** None.

**Management** None.

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## SPEAKERS BANK

**Geographical Location** Northern part of the Chagos Archipelago; 5°S, 72°25'E.

**Area, Depth, Altitude** Total area is 740 sq. km; rim area is 80 sq. km, enclosing a lagoon-shaped depression of 600 sq. km; maximum depth 44 m and average depth of 34-40 m.

**Physical Features** Speakers Bank is a submerged atoll.

**Reef Structure and Corals** No published information is available for this large, submerged reef area; the following is from an unpublished survey by Sheppard in 1979. Two transects were made in the south of the bank, including the reef slope and top of the atoll rim at about 10 m depth. Both show a steep, continuous reef slope without a drop-off, to at least 35 m depth. Below 20 m depth, *Pachyseris speciosa* dominates, while in shallower water there is a high diversity of corals and soft corals whose composition is similar to that of all islanded atolls in Chagos. However, coral cover is much lower in this part of the Bank, rarely reaching 50%. In some parts the seagrass *Thalassodendron* replaces the corals (Drew, 1980). *Millepora* and *Heliopora coerulea* are relatively common on the top of the rim.

**Noteworthy Fauna and Flora** This bank, together with areas on the surface of Colvocoresses Reef (a small reef just east of Speakers Bank) is one of the few places in Chagos where seagrass is currently abundant.

**Scientific Importance and Research** Visited by the 1978/1979 U.K. Joint Services Expedition.

**Economic Value and Social Benefits** Handlining for shark and predatory teleosts has been recorded on the Bank (Frazier, 1977).

**Disturbance or Deficiencies** The reefs have suffered no human interference but corals on one of the two transects examined had undergone massive destruction from *Acanthaster planci*. The infestation had been recent at the time of the survey, as all corals were intact, bleached, and clearly identifiable. The coral kill in the more easterly of the surveyed areas was total at depths greater than 20 m, where there was a clearly defined zone of dead *P. speciosa*.

**Legal Protection** None.

**Management** None.

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## VICTORY BANK

**Geographical Location** 5°32'S, 72°15'E.

**Area, Depth, Altitude** 15.6 sq. km (but Frazier (1977) gives 25 sq. km), of which over half is less than 20 m deep. The shallowest part of the rim is 4 m (according to Landsat derived bathymetry), but more typical depths are 8-10 m; the "lagoon" is an average 25-30 m deep, with a maximum depth of 33 m.

**Physical Features** Victory Bank is entirely submerged, with a typical atoll cross-section and steep seaward slopes descending for a few kilometres. The climatic and oceanographic conditions are similar to those of Salomon Atoll. Rayner and Drew (1984) analyzed dissolved nutrients on a transect across the Bank and observed considerable nitrogen enhancement of the water as it flowed over the reefs (0.18 to 0.46 x $10^{-6}$g-at/l), attributed to nitrogen fixation. Simultaneously, phosphate concentrations fall from 0.56 to 0.19 x $10^{-6}$g-at/l as water passes over the Bank, which is attributed to metabolic uptake.

**Reef Structure and Corals** A brief survey of the reef and its fauna was made in 1979 (Sheppard pers. obs.) but there are no other data. In most respects, the reef slopes and fauna of Victory appear to be similar to those of other atolls of Chagos. The rim has one break (analogous to a pass) in the south. Seaward slopes in the north-west and south-east of the atoll have diverse coral faunas with high cover. Zones of *Pachyseris speciosa* exist between 20 and 30 m, while tabulate *Acropora* species are abundant in shallower water. Above 12 m, *Heliopora coerulea* dominates, except on the top of the rim where sand covers 50% of the surface. Towards the lagoon reef slope, *Millepora* spp. become dominant.

The lagoon reef slope descends steeply to the lagoon floor, which has a high cover of corals, particularly tabulate *Acropora* spp. Knolls, elevated 8 m or more above the floor of the lagoon, are dominated by *Acropora* spp. Generally, coral and hydrozoan cover is over 50% throughout, possibly higher in the lagoon than on the rims. The absence of extensive areas of soft substrate distinguishes the lagoon of Victory from those of the islanded or awash atolls in the Chagos Archipelago, although some sandy patches were observed.

**Noteworthy Fauna and Flora** No information.

**Scientific Importance and Research** The Bank was investigated in the course of the 1978/1979 U.K. Joint Services Expedition.

**Economic Value and Social Benefits** No information.

**Disturbance or Deficiencies** No information.

**Legal Protection** None.

**Management** None.

# COMOROS

## INTRODUCTION

### General Description

The Comoros rise as isolated seamounts of volcanic origin at the northern end of the Mozambique channel, at approximately 12°S, 44°E. The four main islands, Grande Comore, Anjouan, Mohéli and Mayotte, (Ngazidja, Moili, Ndzouani, Maoré) are about 40-60 km apart, flanked to the east by Récif Vailheu and to the west by the Banc du Geyser. The first three islands achieved independence in 1975, but Mayotte at its own request has remained under French administration. Grande Comore is geologically the youngest island, and is the largest (64 x 31 km; 950 sq. km) and highest (2361 m). It is steep-sided, with a rugged coast, 3 m high lava cliffs, pocket beaches, no permanent streams and a paucity of soil and water. Choua-Chandroudé (Ile aux Tortues), about a hectare in area and lying to the north-west, is the only offshore island. Anjouan (35 x 37 km; 378 sq. km; max. alt. 1595 m) is also steep-sided and geologically young, with a similar coastline, but has ample soil and permanent streams and is often considered to be the most beautiful of the islands. There are several offshore rocks but only one significant island, Ile de la Selle (0.3 sq. km), off the west point. Mohéli is the smallest (29 x 12 km, 216 sq. km) and lowest (790 m) island and has ample soil and many permanent streams. A dozen islands lie of the south and south-east (Chissioua M'Chaco, C. Gnandza, C. M'Bouzi (east), C. Chikoundou, C. Foro, C. Méa, C. M'Bongo, C. Chandzi, C. Ouénéfou, C. M'Bouzi (south), C. Canzoni, C. Dzaha and C. Magnougni. Mayotte (38 x 20 km) is the easternmost and oldest of the islands and is generally low and rolling (660 m) with many temporary and several permanent streams (Frazier, 1985; Louette, 1984).

The islands lie in the path of the South Equatorial Current at the point where it divides near the coast of Africa. Tides are semi-diurnal, with an amplitude of 3.5 m during springs. Surface water temperatures vary little, from 24° to 27°C. There are three main seasons: the south-east trade winds predominate from April to September (Kousi), northerly or variable winds predominate from September to November (Niobene) and northerly winds predominate from December to March (Kaskazi). The coolest period is from May to August. Rainfall is variable (850 - 2000 mm a year), most falling between November and April. Guilcher (1971) states that cyclones are frequent and have an important controlling effect on the reefs and the few sand cays but Frazier (1985) states that they are rare. Further details on the climate are given in Ergo (1984).

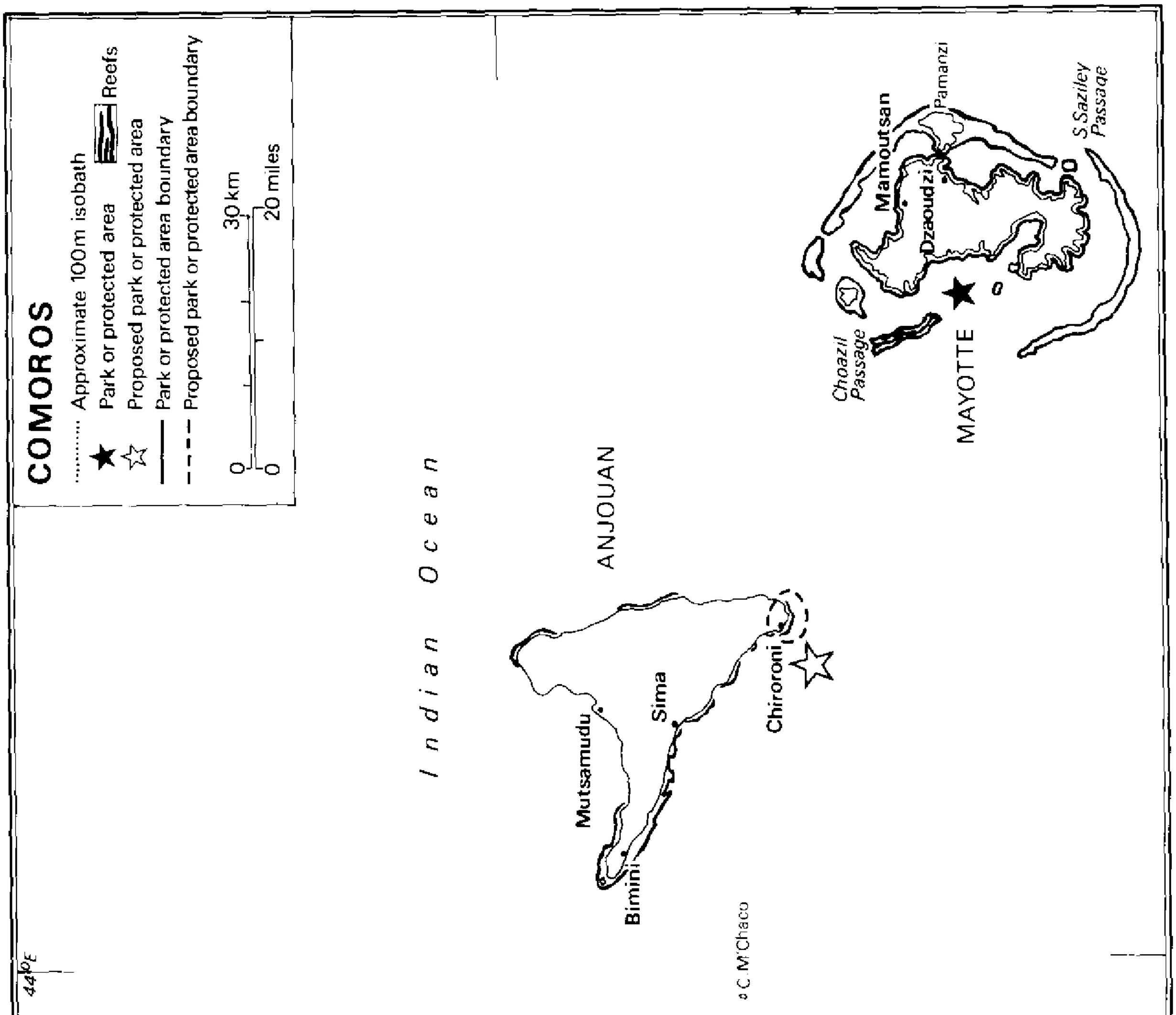
To seaward of the reefs is a shelf a few hundred metres to a few kilometres broad, from which the seabed descends steeply. Fringing reefs are found around the three northern islands but have not been studied, while Mayotte has a substantial barrier reef. General descriptions of the marine environment are given in Hentig (1973), Prosperi (1957) and Frazier (1985). Grande Comore drops steeply to the seabed within a few kilometres of the shore. There are small fringing reefs in the north, north-east, south-east and west, but these cover little more than 60 km of the coast and the majority are very depauperate or even barren. Seagrass beds are restricted to the north-east, near Choua-Chandrondé and cover about 1 sq. km. Anjouan shelves even more steeply and has small fringing reefs on the east and south-west covering less than 55 km of the coast and generally not very rich. Off the western point at Bimbini however there is a complex fringing reef. There are no significanct seagrass beds. Unlike Anjouan and Grande Comore, Mohéli has a relatively extensive area of shallow water, especially in the south, where deep water is only reached more than 10 km for the island. Fringing reefs encircle the island and are most diverse in the south, particularly around the offshore islands. Seagrass beds are also extensive in the south, covering about 5 sq. km. Mayotte has the most extensive area of shallow water and reefs and is described in a separate account.

The Banc du Geyser (46°E, 12°S) lies in international waters. It is a large, horseshoe-shaped reef, submerged at high tide, and it is probably part of the Comoros volcanic chain. It is notoriously dangerous to shipping and has experienced virtually no human impact as a result of its isolation (Polunin and Frazier, 1974).

Mangroves are found in many of Mayotte's protected bays, particularly Baie de Bouéni, and small areas are found on Mohéli (Frazier, 1985). They are relatively undisturbed by man and, due to the influx of terrestrial sediment from the hillsides, some pockets are expanding (UN/Unesco/UNEP, 1982). Fish are described by Fourmanoir (1956). The Comoros are one of the most important breeding areas for the Green Turtle *Chelonia mydas*; Mohéli, in particular, has major nesting beaches, especially on C. Ouénéfou, and good numbers nest on Mayotte. The Hawksbill Turtle *Eretmochelys imbricata* also nests in the group, but in smaller numbers (Frazier, 1985). Marine molluscs are described by Backeljau (1984). The Coconut Crab *Birgus latro* is found in the Comoros (Fourmanoir, 1953; Jocque, 1984). There is a breeding population of White-tailed Tropicbirds *Phaethon lepturus*, although the number of pairs is unknown (Feare, 1984). Chissioua M'Chaco and C. Magnougni, off Mohéli, are important seabird nesting sites (Draulans *et al.*, 1985; Noman, 1983).

### Reef Resources

Apart from some subsistence farming and fishing, the economy of the islands has depended to a large degree on the export of specialized agricultural crops. There is no large commercial fishery and the artisanal fishery is insufficient to meet the needs of the population. Exploitation is intense, partly because the limited area of shallow water (Frazier, 1985). Reef fishing is particularly important in the three western islands. In 1983, modern boats with engines were obtained by the Government from Japan and this could lead to intensification of the fishery (Louette *in litt.*, 16.10.86). An early description of the fishery is given in Fourmanoir (1956). Banc du Geyser and Banc de la Zelée, once used by Réunion fishermen, are now used by fishermen from M'Zamboro and M'Tsaara on Mayotte (Le Gall, 1986). The Mayotte fishery is described in the following account.


COMOROS
Approximate 100m isobath
Park or protected area
Proposed park or protected area
Reefs
Park or protected area boundary
Proposed park or protected area boundary
0
30 km
0
20 miles
Indian Ocean
GRANDE COMORE
Mitsamiouli
Bangoi-Kouni
Ivoni
Choua-Chandroudé
Moroni
Malé
Chindini
MOHÉLI
Fomboni
Nioumachoua
C. M'Chaco
C. Ouénéfou
C. Magnougui
ANJOUAN
Mutsamudu
Sima
Chironi
Bimini
MAYOTTE
Mamoutsan
Dzaoudzi
Pamanzi
Choazil Passage
S Saziley Passage
44°E
12°S

At present tourism is not important but there are plans to develop it (Salm, 1983). A limited amount of reef-related activities are available through hotels, and expatriates dive at weekends (Louette *in litt.*, 16.10.86). Diving arrangements can be made on Grande Comore, Moroni and Mayotte, and diving cruise boats and charter boats make trips through the islands and to Banc du Geyser (Anon., 1986). Spearfishing safaris are organised from some of the hotels. Banc Bayeux, an hour from Grande Comore is considered a good diving site, but some of the best sites are around the Nioumachoua islands off Mohéli (Anon., 1974).

**Disturbances and Deficiencies**

The impact of early outbreaks of the Crown-of-Thorns starfish *Acanthaster planci* is described by Polunin (1974). In 1983, there was a severe outbreak of coral bleaching and mortality on the Mayotte reefs (*see separate account*) which may have been related to the abnormal El Niño that year (Glynn, 1984).

Subsistence farming has put a severe strain on the natural resources of the upland areas and, with the collection of firewood, has caused erosion of the landscape to a critical point (UN/Unesco/UNEP, 1982). This is expected to increase further with the growing population, now reported to have the highest density in Africa (over 200/sq. km) (Griffin, 1986). Siltation has already had a marked impact on reefs and the coastal region, particularly on Mayotte (*see separate account*), and Anjouan where erosion has had a noticeable impact on the coastal ecosystem at Presqu'île de Sima (Noman, 1983). The siltation is also considered to be lowering fish productivity (World Bank, 1979).

The direct mining of reef rock and extraction of beach sand for building purposes are problems. Live coral is also taken from the reefs and burned to make lime and cement, large quantities of indigenous wood being consumed as fuel. This has caused widespread beach erosion and former reef areas and nearshore lagoons have been transformed into mud flats, especially in Anjouan where coral is mined at a number of sites. Erosion is also affecting coastal roads. The situation appears to be difficult to alleviate and is expected to deteriorate (Finn, 1983). Overfishing of lobsters has been reported and there has been a rapid rise in prices recently (Louette *in litt.*, 16.10.86). Fishing with dynamite and poison is reported to be a problem (Noman, 1983). The growth of the tourist industry with emphasis on diving and spearfishing safari may have an impact on the reefs if such activities are not controlled. The turtle fishery is of little importance (Frazier, 1985).

**Legislation and Management**

Mayotte comes under French legislation and is described in the following account. On the other three islands, environmental problems are dealt with by the Ministry of Equipment, Environment and Urbanisation and the Ministry of Production, Industry and Art. The latter manages fisheries, fauna, flora, agriculture and forests through the Central Federal Directorate for Rural Development. The Fisheries Department is managed in conjunction with the Society for Development of Fishing in Comoros (SODEPEC). Fishing with dynamite and poison is strictly prohibited although poorly enforced, but there is no legislation to regulate the quantities of fish or marine invertebrates taken. Turtles are not protected but Dugongs *Dugong dugon* are said to be, although no information on this legislation could be obtained by Frazier (1985). There is a law to control coral and sand removal but this is not enforced (IUCN, 1987).

**Recommendations**

SODEPEC intends to create Marine Parks in the following areas (Noman, 1983):

- The Nioumachoua Islets (Wenefou and Boinaidi) (5 ha), off Mohéli, are proposed as a strict Nature Reserve with fishing prohibited and only open to scientists. Dugong are found along this coast. Around the islets, a buffer zone will be created in which artisanal fishing will be permitted.
- Marine areas between Bangoi Kouni and Ivoini, and Chindini and Malé (in the north and south of Grande Comore respectively) will be marine parks in which artisanal fishing will be permitted.
- Chironi, in south Anjouan, is proposed as a protected area in which artisanal fishing will be permitted.

Frazier (1985) recommends the creation of a reserve system for the beaches and reefs of Chissioua Ouénéfou, off the south of Mohéli, which would include three of the six major turtle nesting beaches in the Comoros and some of the richest reefs. The turtle nesting beach on Pamanzi Island, off the east coast of Mayotte, should also be protected. Proposals have been made for the creation of a large marine and terrestrial reserve in the south of Mayotte, with additional small reserves in other areas (*see separate account*).

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## MAYOTTE BARRIER REEF

**Geographical Location** Southernmost island of Comoros group; 12°30'S, 45°10'E.

**Area, Depth, Altitude** Mayotte is 38 x 21 km (370 sq km), and 660 m high; barrier reef extends for 140-150 km; lagoon width 3-15 km, with a depth of over 30 m in most places and up to 80 m in the south-west (Guilcher, 1971); inner south-west lagoon maximum depth 30 m. The seaward slope of the latter descends rapidly to 500 m and more (Guilcher, 1965).

**Physical Features** Mayotte is of volcanic origin and is almost entirely surrounded by a barrier reef. It consists of two parts, Grande Terre and Petite Terre with several small offshore islands. The geological structure of the barrier reef is described by Coudray *et al.* (1985), Guilcher (1965 and 1971) and Guilcher *et al.* (1965). It lies 3-15 km off shore, sheltering a deep lagoon, which generally slopes towards the island, the shallower parts lying near the barrier reef. There are at least nine passages of navigable depth in the south and east where the reef is well developed. In the north-west, it is more or less drowned and less continuous. The deep passages and lagoon are probably the result of past subaerial erosion during low sea-levels in the last glaciation.

Despite its length, the barrier reef supports only four small cays. One is located on each side of South Saziley Passage in the south-east, while the other two are located beside Choazil Passage in the north-west. All are unconsolidated sand cays, apparently devoid of beach rock and submerged at high spring tides. Their shape is consequently variable, and they support no vegetation. Their location beside passages is probably related to wave refraction and the interruption that the channels make to the longshore drift of sand. Guilcher (1971) attributes the overall scarcity of sand cays on the Mayotte Barrier Reef to the high (3.5 m) spring tidal range, and to frequent cyclonic disturbances, although he points out that at least two of the present cays have existed for 150 years.

A second, inner barrier reef is found in the lagoon to the south-west. Fringing reefs border much of mainland (Frazier 1985; Guilcher, 1965). The lagoon is dotted with about a dozen islands and many patch reefs.

**Reef Structure and Corals** The broad barrier reef, nearly 2 km wide in places such as the north-east, has several faroes, small structures formed where the distal edges of a part of the reef have recurved to leeward to form a ring. The enclosed lagoon may be 20 m deep and cut off from the main barrier reef lagoon at low spring tides. Pinnacles arise from the lagoon floor near the barrier which have much dead coral, with living sponges and *Halimeda*, but also living corals to at least 40 m. The outer edge of the reef flat does not have an algal ridge, but spurs and grooves are a conspicuous feature. The outer slope is described as very steep, dropping from 55 to 360 m, but no details of slope ecology are available. The inner barrier is still growing and small lagoons are being formed.

Prior to the coral mortalities observed in 1983 (*see below*), stony coral cover on the fringing reefs amounted to 10-36%; on lagoonal patch reefs and slopes of the fringing reefs 50-60%, and on the barrier reef 55-70%. The reef crest is dominated by old dead *Acropora palifera* with only 5-16% live coral cover (Faure *et al.*, 1984).

**Noteworthy Fauna and Flora** Seagrass beds, covering a total of about 100 sq. km are common in the lagoon and on the outer edge of the barrier reef. An estimated 500 Green Turtles *Chelonia mydas* and 25 Hawksbill *Eretmochelys imbricata* nest annually, perhaps three-fifths of the Greens on Pamanzi, a satellite islet to the north-east of Mayotte (Frazier, 1985). Some of the reef fish of Mayotte are described by Fourmanoir (1963).

**Scientific Importance and Research** The barrier reef of Mayotte is one of the few barrier reefs, and the best developed, in the Indian Ocean. It has been well documented, from the geological aspect, by Guilcher (1965 and 1971) and Guilcher *et al.* (1965) but there is very little published biological data. A number of research projects however, are now underway and there are proposals for expanding this programme, which is largely undertaken through the Université d'Aix-Marseille (Thomassin *in litt.*, 28.11.86).

**Economic Value and Social Benefits** Koechlin and Boyé (1984) and Le Gall (1986) provide descriptions of the Mayotte fisheries. Artisanal fishing is carried out in the lagoon and, when the weather permits, on the reef front. The fishery has increased considerably recently and there are now over 1000 boats, of which about 300 have motors. Total productivity is about 600-800 tonnes a year.

Tourism is being promoted on the island but hotel development is still limited (Koechlin and Boyé, 1984). The N'Gouja holiday village on the south coast caters specially for divers; there are also hotels on Dzaoudzi. Because of the distance of the barrier reef from the main island, diving cruises are arranged through the lagoon and to other islands (Anon., 1974 and 1986). The best recreational beaches are in the north near M'Zamboro, at Bandélé, Pamanzi and Longoni.

**Disturbance or Deficiencies** Severe coral bleaching and mortality was observed from May to June 1983, following a gradient from the reef flat and slopes of the fringing and internal reefs, to the barrier reef and seaward slope from 0 to 12 m depth, the fringing and lagoon reefs being most seriously affected. On the fringing reefs, the corals *Montipora, Acropora, Millepora intricata* and *M. tenera* were found to be completely bleached; Faure *et al.* (1984) provide a list of other species which were affected. From 0 to 18% of the total stony coral cover was affected. On patch reefs in the lagoon and the slopes of fringing reefs 30-45% of the stony corals were affected. On the barrier reef 30-75% were affected, especially acroporids, poritids, faviids and milleporids. The reef crest was little affected. On the seaward slope, from 0 to 12 m, bleaching was limited to the edge and centre of tables of *Acropora hyacinthus*, the extremities of branches of *A. palifera* and some massive *Porites lutea*. The temperature of the lagoon however was unusually high (reaching 29°C), turbidity was high and oxygen saturation was low. This led to the suggestion that these events were linked to the abnormal El Niño that year (Glynn, 1984). *Acanthaster* predation was low at the time, although there have been infestations in previous years (Arnoux *et al.*, 1983; Koechlin and Boyé, 1984).

However, other studies (Arnoux *et al.*, 1983; Koechlin and Boyé, 1984) have suggested that human activities may also have been responsible. The population of Mayotte increased from 23 364 in 1958 to 52 035 in 1980 and there has been extensive erosion as a result of widespread deforestation. This has almost certainly contributed to the massive increase in the amount of terrigenous sediment present in the lagoon and severe damage to the fringing reefs (Guilcher, 1985; Koechlin and Boyé, 1984). There are just a few areas which have not been affected by siltation such as M'Zamboro in the north. The barrier reef and patch reefs in the lagoon have also avoided serious siltation, being further from the coast (Koechlin and Boyé, 1984). Direct excavation of coral rock and sand for building materials has also been having a major impact.

The increased sedimentation in the lagoon may also be affecting the fisheries. Fourmanoir and Harmelin-Vivien (1984) have recorded a change in fish population structure recently, with a lower species diversity and an increase in the number of herbivorous species, presumably in response to the increasing amount of algae on the reef. Fishing with poison was once widespread but has now largely ceased.

The tourist industry is likely to have an increasing impact. Shell collecting on the fringing reefs is already considered excessive. Shells have always been taken for traditional purposes but are increasingly taken for sale to tourists (Koechlin and Boyé, 1984).

**Legal Protection** Mayotte comes under French legislation. Law 60.708 of 22.7.60 applies to the establishment of National Parks and the Loi sur la Protection de la Nature, 10.7.76 also covers environmental protection. Fishing in the lagoon is only allowed with government permission and this area is therefore considered protected to a certain extent (Noman, 1983). Fishing with poison is prohibited and a two year moratorium on spearfishing was introduced in August 1977, but now appears to have been lifted (Koechlin and Boyé, 1984).

**Management** The Association pour la Protection du Lagon (APROLAM) is a private organisation established to encourage appropriate management of the reefs and lagoon (Koechlin and Boyé, 1984).

**Recommendations** A six week survey of the ecology and environment of Mayotte was carried out by the Société pour l'Etude, la Protection et l'Aménagement de la Nature dans les Régions Inter-Tropicales (SEPANRIT) in order to make management and policy recommendations (Koechlin and Boyé, 1984). There is an increasing need to control tourism and limit reef activities to diving, photography and other pursuits which do not damage the reefs. Shell collecting and spearfishing must be controlled and a protected area system is required, perhaps including rotating reserves as on Réunion. Perhaps most important is the need for monitoring and research on the major problem of siltation and its long term impact on the reefs, tourism and fisheries. Recommendations have been made to the Préfecture by Thomassin (*in litt.*, 28.11.86) which include the creation of a large terrestrial and marine reserve in the south to include portions of the reef, the islet of Saziley and a variety of other habitats. Other reserves are also being proposed around the island.

Koechlin and Boyé (1984) and Le Gall (1986) make recommendations for the improved management of the fishing industry, which could perhaps be carried out through the Ecole de Pêche at Iloni. The legislation needs revision and traditional fishery methods should be developed. There is considerable scope for aquaculture and this should be encouraged to relieve pressure on fishery stocks. The turtle nesting beach on Pamanzi Island has been recommended for protection (Frazier, 1985).

# DJIBOUTI

## INTRODUCTION

### General Description

Djibouti has a coastline of about 370 km, a third of which faces the narrow Bab el Mandeb and the remainder lying along the narrow Golfe de Tadjoura, between Obock in the north and the port of Djibouti in the south. Gravier (1908, 1910a, b, c and 1911) gave a detailed description of the reefs in the Golfe de Tadjoura. Three reefs, Récif Jousseaume (which is attached to Pointe-Noire), Récif d'Ambouli (Bonhoure) and Banc des Salines (Ormières), lie to the west of the port of Djibouti. To the north lie a series of emergent reef rock platforms, the largest, Héron, forming an island at high tide. These were surrounded by fringing reef at the beginning of the century. Small patch reefs were also present in the waters surrounding these platforms. To the north-west lie the reefs of Météore and Pingouin. Billard (1904) described hydroids from the Golfe de Tadjoura. The Ardoukoba expedition to Djibouti (December 1984-February 1985) surveyed the marine flora and fauna and the reefs particularly around the islands of Musha and Maskali (*see separate account*), at Obock (the fringing reef Laclocheterie and two smaller offshore reefs, Surcouf and Bisson, described by Gravier (1911)), Tadjoura, Goubbet el Kharab and to the west of Djibouti port. Reefs are also found in the archipelago of the Sept Frères (Seven Brothers), at the entrance to the Red Sea. The reefs are generally shallow although corals have been found at over 35 m depth at Ras Duan (Anon., 1985).

Although giving no specific reference to Djibouti, Cooper *et al.* (1984) describe breeding seabirds on the islands off Saylac (Zeila), Somalia, which are just over the southern border of Djibouti. Of the six species described, the Bridled Tern *Sterna anaethetus* occurs in hundreds of thousands. Marine Turtles are known to nest, apparently not in large numbers; Green *Chelonia mydas* and Hawksbill *Eretmochelys imbricata* products are recorded in markets (Anon., 1982).

### Reef Resources

A systematic inventory of fish, particularly commercial species, has been carried out in the Golfe de Tadjoura by the Institut Scientifique et Technique des Pêches Maritimes (Frontier, 1978). The Institut Supérieur d'Etudes et de Recherches Scientifiques et Techniques (ISERST) has initiated a marine research station and has donated diving and photographic equipment. A collection of local corals has been started and a project on reef fish initiated. It is hoped that foreign scientists will work there, if international financial assistance is available.

Tourism is being developed and much of it will be marine-related. For example there are plans to develop six small-scale resort areas along the coast (ODT, 1984).

### Disturbances and Deficiencies

Near the port of Djibouti, the reefs described by Gravier (1908) as flourishing, are still alive but are rapidly becoming silted. Overfishing is reported to be serious in the Golfe de Tadjoura. There is extensive recreational fishing by expatriates, particularly the military (ODT, 1984). Collection of corals and shells, spearfishing, dredging, anchor damage, explosions in the course of military activities, boat traffic and increasing water turbidity are also cited as problems. Bab el Mandeb is a source of pollution on account of the large volume of vessel traffic (Laurent *in litt.*, 4.10.86).

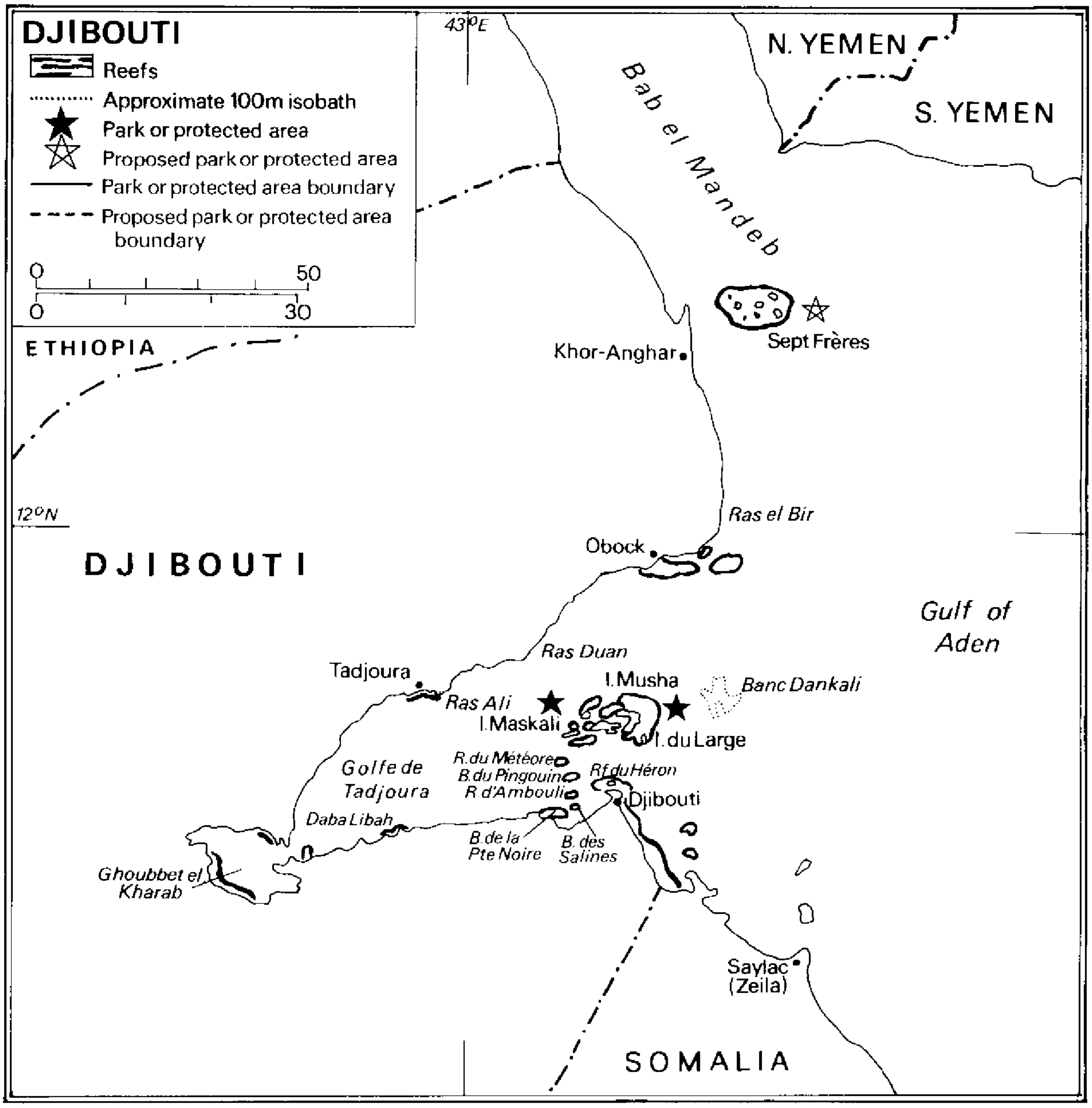
### Legislation and Management

Djibouti is a signatory of the African Convention on the Conservation of Nature and Natural Resources and of the Indian Ocean Alliance. Ile Musha has been designated as a Parc Territorial, within which there is a réserve intégrale around the south of Ile Maskali (*see separate account*). ISERST and the Office de Developpement du Tourisme (ODT) are responsible for administration. Arrete No. 72-1363 SG/CG, which designated the Parc Territorial de Musha, also declared the following areas as reserves for five years: Réserve de Tadjourah, Réserve d'Obock and Réserve d'Arta, within which fishing by traditional methods was permitted but all other forms of fishing, as well as the collection of corals and shells was forbidden. The status of these areas at present is not known.

Decret No. 80-062/PR/MCTT of 1980, in addition to designating the Ile Maskali reserve, prohibiting (for the time being) the export of reef fish and the collection of shells, and banning the collection, sale and export of dugong, turtles and their eggs, placed a number of restrictions on spearfishing. However, in 1985, a decree was passed prohibiting spearfishing completely (Toulemont *in litt.*, 17.10.86).

### Recommendations

Recommendations for further research in the Golfe de Tadjoura are given in Anon. (1985). There is an urgent need to bring together local scientists to study the potential for conservation and exploitation of the reefs. Action urgently needs to be taken to protect the reefs near the port of Djibouti. A study on the potential for tourism in Djibouti makes a number of recommendations concerning environmental management (ODT, 1984). It is suggested that there should be a moratorium on fishing by non-professionals in order to allow species in the Golfe de Tadjoura to regenerate; authorised fishing zones could be moved to the north, to areas in the Red Sea where over-exploitation has not been reported. Total protection of the islands and of the Sept Frères is recommended on account of their seabird colonies. The sale of corals, birds eggs, and tortoiseshell should be prohibited.


DJIBOUTI
Reefs
Approximate 100m isobath
Park or protected area
Proposed park or protected area
Park or protected area boundary
Proposed park or protected area boundary
0 50
0 30
43°E
12°N
N. YEMEN
S. YEMEN
Bab el Mandeb
Sept Frères
Khor-Anghar
ETHIOPIA
DJIBOUTI
Ras el Bir
Obock
Gulf of Aden
Ras Duan
Tadjoura
I. Musha
Banc Dankali
Ras Ali
I. Maskali
I. du Large
R. du Météore
B. du Pingouin
R. d'Ambouli
Rf. du Héron
Golfe de Tadjoura
Djibouti
Daba Libah
B. de la Pte Noire
B. des Salines
Ghoubbet el Kharab
Saylac (Zeila)
SOMALIA

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## PARC TERRITORIAL DE MUSHA (MOUSCHA) AND RESERVE INTEGRALE DE MASKALI SUD

**Geographical Location** At the mouth of the Golfe de Tadjoura. The Parc Territorial covers the coral reef from the lighthouse at Musha to the Ile du Large, with the exception of the Banc Dankali. The Réserve Intégrale de Maskali Sud lies within the National Park, covering the area from Maskali lighthouse to the large coastal sandbank; 11°40'N, 43°10'E.

**Area, Depth, Altitude** 3-25 m depth; max. alt. 5 m.

**Land Tenure** Government owned.

**Physical Features** The islands of Musha and Maskali represent the remains of an ancient coral platform, dating from the Pleistocene or earlier, which has been heavily eroded. The platform is broken by channels, tens of metres deep. Modern reefs have developed on the platform around the islands, and are particularly well developed in the north and north-east; in other areas patch reefs are found. The reefs drop to a depth of 15 m where there is a gentle sandy slope. Further details of the topography and geology of the area are given in Anon. (1985). Winds are predominantly from the north-east. The islands are arid with no freshwater (Gravier, 1911).

**Reef Structure and Corals** About 80 species of hermatypic corals have been recorded. Calcareous algae, octocorals and *Millepora* appear to be relatively insignificant compared with similar reefs in the Red Sea and Indian Ocean. In comparison, the stony corals are remarkable for their abundance and the size of the colonies, particularly towards the south-west, near the Ile du Large to the south of Musha. The relatively turbid water limits coral growth to depths of between 15 and 25 m (Anon., 1985).

**Noteworthy Fauna and Flora** Populations of sponges of commercial value were found in the rocky zone around the islands, but are not sufficiently abundant to merit exploitation (Anon., 1985).

**Scientific Importance and Research** The reefs of the Golfe de Tadjoura are considered scientifically interesting on account of the rich coral growth. Studies on bryozoans, sponges, fish, algae and seagrasses were carried out in the course of the Ardoukoba expedition to Djibouti (Anon., 1985).

**Economic Value and Social Benefits** There is considerable potential for reef-related tourism (Anon., 1985). The islands are already heavily used at weekends by expatriates and there are plans to develop a "beach-club" on Musha (ODT, 1984). The islands were once used occasionally by fishermen (Gravier, 1911) and probably still are.

**Disturbance or Deficiencies** Over-collection of shells has been a problem.

**Legal Protection** The Parc Territorial was established in 1972 under Arrete No. 72-1363/SG/CG and the Réserve Intégrale in 1980 under Decret No. 80-062/PR/MCTT.

**Management** Administered by ISERST and ODT.

**Recommendations** Local research scientists are anxious to improve protection of these reefs, hopefully concurrently with the development of tourism (Anon., 1985; ODT, 1984). There are plans for a mobile underwater observatory and a beach club or resort.

## INTRODUCTION

### General Description

The coast of Egypt is 2420 km long and comprises four sections: the east side of the Sinai Peninsula bordering the Gulf of Eilat/Aqaba; the west side of the Sinai Peninsula and the northern part of the mainland coast both surrounding the Gulf of Suez; the southern part of the mainland bordering the Red Sea proper; and the Meditteranean. The two gulfs, separated by the Sinai Peninsula, are very different in physical characteristics.

The Gulf of Aqaba is 170 km long, 14-26 km wide and forms part of the Afro-Syrian Rift System. It has steep walls dropping to great depths (almost 2000 m in places) and is separated from the Red Sea by the 6 km wide Straits of Tiran. There are two major marine basins, the northern one extending south to Nuweiba with depths of 1000 m; the southern one extending to Tiran with depths of 1800 m. Sediment is not re-suspended significantly due to the great depth and the waters are therefore generally exceptionally clear. Freshwater inflow is low and evaporation is high, causing high salinities. Water temperatures range from 21°C (19°C) at the bottom to 26°C at the surface and during the summer increase to 27-29°C in shallow inshore waters. The water is usually calm, although wave action from the prevailing northerlies builds to a peak at Dahab and decreases again towards Tiran. There are rare southerly storms.

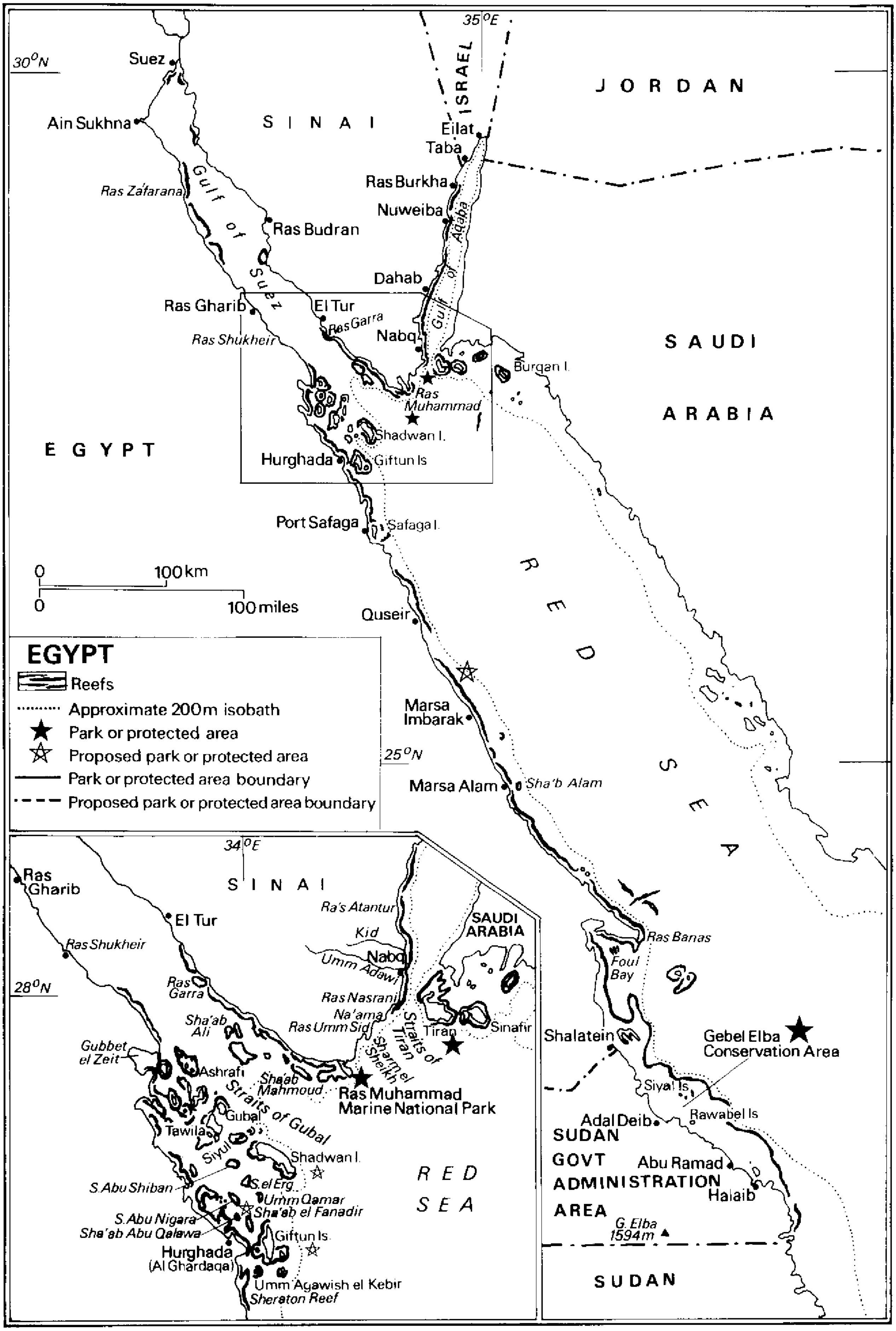
The Sinai coast stretches along the Gulf of Aqaba for about 250 km from the border with Israel to Ras Muhammad (Ras Mohammed). From Eilat to Ras Atantur there is a long narrow shore with mountains descending almost directly into the sea. The coastal strip from Ras Atantur to Ras Nasrani is up to 5 km wide and is influenced by the deltas of Wadis Kid and Umm Adawi. From Ras Nasrani to Ras Muhammad the beaches are progressively replaced by raised fossil reefs. Fringing reefs extend along most of the entire shoreline of the southern part of the Sinai Peninsula, partly interrupted by shallow bays, as at Dahab and Nuweiba where wadis become large deltas. In such places winter floods of fresh, silty water inhibit reef growth. The width and thickness of the fringing reefs depends on the steepness of the slopes on which the corals rest. Fishelson (1980) describes "lagoonar" reefs, "platform" reefs (more typical of the southern part of the Gulf such as Ras Atantur and from Ras Nasrani to Ras Muhammad), "contour" reefs (found south of Dahab), sharem reefs (found around and within bays), and "coral islet" and "mangrove" reefs.

Cohen (1975) gives brief descriptions of some of the more popular diving sites and provides the only easily available information for reefs on this coast. Coral Island (29°27'N) (350 x 150 m), just to the south of the Israeli border, is separated from the shore by a deep channel, 220 m wide. It has steep slopes especially on the eastern and northern sides, but the southern side is flatter and has a patch reef 10 m off shore (Fishelson, 1980). At Fijord, further south, there are several reefs. Marsa El Muqabila, 26 km south of Eilat, is a wide deep bay 1 km long, and has one of the richest reefs in the area. A narrow reef runs parallel to the embankment, and then drops to an area of abundant coral and coral knolls. Ras Burkha is described in a separate account, although little information is available.

At Big Ruta, 1 km south of Ras Burkha, there is a solitary large patch reef off shore in 10-20 m of water, with a rich collection of pipe sponges. Maagana (Devil's Head), a prominent solitary rock on the coast further south, 15 km north of Nuweiba, is surrounded by vertical reef to 15 m depth, and has abundant large fish and sharks. It is described in detail by Fishelson (1980) who considers it to be the best in the northern part of the Gulf. Nine kilometres to the north of Dahab a reef runs parallel to the shore at depths of 6-8 m, followed by a sandy slope with coral to 50-60 m depth. A canyon here was once a popular dive site as was a deep hole in the reef 2 km to the north. At Dahab itself the reef runs parallel to the shore and has a vertical wall to 30-40 m depth with diverse life and a few large coral patches off shore. Seven kilometres to the south there is a small reef 10 m wide with coral to 3-6 m depth, followed by a steep sandy slope with numerous coral knolls and patches. The area around Nabq is important for its mangroves *Avicennia marina* (Fishelson, 1980; Por *et al.*, 1977). At El Arkana, just north of Nabq, there is a shallow reef table 60 m off shore with reef knolls on a sand bottom. Towards the south the reefs and scenery become increasingly spectacular culminating in Ras Muhammad and reefs in the Straits of Tiran (*see separate accounts*).

A high coral diversity has been recorded on these reefs although they have a simplified structure. About 129 species of hermatypic corals (Scheer and Pillai, 1983) and almost 120 species of soft corals have been recorded. Soft corals of the Sinai Peninsula are described by Benayahu (1985). *Millepora dichotoma* and *M. platyphyla* form dense belts along many coral platforms. Fishelson (1980) describes other corals typical of the Gulf. An analysis of fish communities at Nuweiba was carried out by Ben-Tuvia and Baranes (1982) and reef fish studies have also been carried out by Fishelson *et al.* (1974). From 1980 to 1981, topographical descriptions were made along of Sinai coast, community structure was described and studies on percent cover, species distribution and abundance were carried out to a depth of 40 m (Schlesinger *in litt.*, 29.2.84). Published material resulting from these studies had not been obtained at the time of going to press.

The Gulf of Suez is a wide shallow basin, with an average depth of 20-30 m, greater depths in the central trough and a depth of 80 m at the entrance to the Red Sea. In the Strait of Gubal (Jubal), currents may reach over 100 cm/sec due to the northerly winds and 30 cm semi-diurnal tidal oscillations (Roberts, 1985). The hydrography and chemistry of the Gulf of Suez are described by El-Sabh and Beltagy (1982) and additional information is given by Roberts (1985). It has a soft sediment bottom and wave agitation of the shallow water causes increasing sedimentation north from the Red Sea (Fishelson, 1980). There is much wind-swept sand on the Sinai side. Winter temperatures are cool (Pearse, 1982). In the north, water and faunal exchange with the Mediterranean takes place through the Suez Canal


30°N
35°E
Suez
Ain Sukhna
SINAI
ISRAEL
JORDAN
Eilat
Taba
Ras Burkha
Nuweiba
Ras Za'farana
Gulf of Suez
Gulf of Aqaba
Ras Budran
Dahab
Ras Gharib
El Tur
Ras Garra
Nabq
Ras Shukheir
Burqan I.
SAUDI ARABIA
Ras Muhammad
Shadwan I.
EGYPT
Hurghada
Giftun Is
Port Safaga
Safaga I.
0 100km
0 100 miles
Quseir
RED SEA
EGYPT
Reefs
Approximate 200m isobath
Park or protected area
Proposed park or protected area
Park or protected area boundary
Proposed park or protected area boundary
Marsa Imbarak
25°N
Marsa Alam
Sha'b Alam
34°E
Ras Gharib
SINAI
El Tur
Ra's Atantur
Kid
SAUDI ARABIA
Ras Shukheir
Nabq
Umm Adawi
28°N
Ras Garra
Ras Nasrani
Na'ama
Sha'ab Ali
Ras Umm Sid
Straits of Tiran
Sharm el Sheikh
Gubbet el Zeit
Tiran
Sinafir
Ashrafi
Sha'ab Mahmoud
Ras Muhammad Marine National Park
Straits of Gubal
Gubal
Tawila
Siyul
Shadwan I.
S.Abu Shiban
S.el Erg
Umm Qamar
Sha'ab el Fanadir
RED SEA
S.Abu Nigara
Sha'ab Abu Qalawa
Giftun Is
Hurghada (Al Ghardaqa)
Umm Agawish el Kebir
Sheraton Reef
Ras Banas
Foul Bay
Shalatein
Gebel Elba Conservation Area
Siyal Is
Adal Deib
Rawabel Is
SUDAN GOVT ADMINISTRATION AREA
Abu Ramad
Halaib
G. Elba 1594m
SUDAN

(Fishelson, 1980; Ormond, 1976). This, and the endemic species of the Gulf, are of particular biological interest (Ormond, 1976) as is the recent nature of the marine ecosystems (Clark and Vanderbilt, 1982; Fishelson, 1980). Pearse (1982) has studied the effect of extreme physiological stress on Indo-Pacific species in the Gulf.

Fringing reefs in the Gulf of Suez are less well developed than those in the Gulf of Aqaba. From Port Suez at the southern extremity of the Suez Canal southward to Ras Shukheir, the bottom is mainly calcareous sand. In the northern half of the Gulf there is little or no coral, the northern limit on the western shore being at Ain Sukhna. Suez Bay has a sand and mud bottom with coral limited to boulders and rocky outcrops. From Ain Sukhna to the Strait of Gubal only patchy fringing reefs with much dead coral and considerable cover of brown seaweed are found (Ormond, n.d.). In the southern half of the Gulf there are moderately developed reefs (Fishelson, 1980). Surveys of the shores, lagoons, fringing reefs, subtidal coral knolls and ridges at Ras Budran, on the eastern shore (28°57', 33°11'E) have been carried out by Dicks (1984) and OPRU (1980 and 1983a). The reef at Ras Garra is described briefly in a separate account. On the western shore, the coastal lagoons, fringing reefs and offshore sediments at Ras Gharib (28°23'N, 33°7'E) are described in OPRU (1983b). Coral diversity is limited, 25 species having been recorded by Rosen (1971) and more recently 45 by Scheer and Pillai (1983).

The Ashrafi reef complex, consisting of two small platforms on the west side of the Strait of Gubal, is described by Roberts (1985). The platforms have a stream-lined shape due to wave-stimulated reef accretion on the northern ends and down drift sedimentation to the south, resulting from strong tidal currents and unidirectional wind drift from the north. There is little coral growth on the platform tops probably due to the high salinities which develop there, but there is abundant coral on the windward reef crest at the edge of the platform and on the fore-reef which slopes gently to the north with *Acropora, Porites, Platygyra, Pocillopora, Alcyonium* and *Stylophora*. A description of the reefs and sediments at 35 locations in Zeit Bay and among the Ashrafi, Qeisum and Gubal Islands is given in OPRU (1983c). Reefs around some of these islands and others to the south are described in the account for the proposed Shadwan Marine Park.

In the Red Sea proper, the section of the Egyptian coast from Ras Shukheir southwards to Quseir is faunistically very rich. The reefs around Hurghada (Al Ghardaqa) have been studied in the course of a series of expeditions (*see accounts for* Giftun Islands, Hurghada proposed National Park, Hurghada Marine Biological Station). The coastline from Quseir to the southern border is rarely visited and has been little studied (Beltagy, 1976) (*see account for* Southern Egypt). Further south, reefs occur around the offshore islands in the Sudan Government Administration Area but have not been studied (*see account for* Gebel Elba Conservation Area).

A general description of the marine fauna of the Red Sea is given in the Introduction to this volume. Green Turtles *Chelonia mydas*, Loggerheads *Caretta caretta*, Leatherbacks *Dermochelys coriacea* and Hawksbills *Eretmochelys imbricata* are reported breeding on the Sinai coast (Fishelson, 1980; Frazier and Salas, 1984; Groombridge, 1982; Ross and Barwani, 1981; Sella, 1981). Nesting also occurs at Ras Muhammad and on Tiran and Sinafir Islands (Groombridge, 1982). Cooper *et al.* (1984) list four species of seabirds nesting in the Gulf of Suez Islands, including three terns *Sterna* spp., the Brown Booby *Sula leucogaster* and possibly the White-eyed Gull *Larus leucophthalmus*. Comparative studies of populations of *Echinometra mathaei* have been carried out in the Gulf of Suez and the Gulf of Aqaba (Lawrence, 1982). There are a number of publications on the fish fauna including Ormond (1980b) and Randall (1983).

The laboratory of Marine Biology of Al-Azhar University and the Hurghada Marine Biological Station have carried out surveys and compiled reference collections of marine fauna and flora. Early work on the reefs was carried in the course of the John Murray/Mabahess Expedition (Anon., 1939). A marine research station is being established by the Suez Canal University at Ras Muhammad. The Tropical Marine Research Unit (York) undertook several visits to the Egyptian Red Sea between 1977 and 1980 under the auspices of the Egyptian Institute of Oceanography and Fisheries, to advise on requirements for marine conservation (Ormond, 1981). General information on the Red Sea reefs is given in Bermert and Ormond (1982).

**Reef Resources**

The Gulf of Suez is probably the most productive fishing zone in the Red Sea (Beltagy, 1976) although purse seine fishing estimates for the Gulf show a recent decrease in catch (Shaheen *et al.*, 1982). Fisheries in the Red Sea area are described by El-Mahdy (1982). There are plans to develop the Sinai coast for food production (Clark and Vanderbilt, 1982). The Sinai Peninsula is being developed for tourism and already attracts some 100 000 visitor days a year, a figure which could rise to 200 000-400 000 in 1990. There are diving centres at Nuweiba, Na'ama Bay and Sharm el Sheikh, the latter being the most important (*see account for* Ras Muhammad). The Hurghada area also receives large numbers of visitors and is a popular diving resort (*see separate accounts*). Information on tourism in the Red Sea area is given in Taher (1981).

**Disturbances and Deficiencies**

In the 1970s, considerable disturbance occurred to many reefs, particularly the outer ones, as a result of abnormally high numbers of sea urchins, particularly the large black-spined urchin, *Diadema setosum* but also *Heterocentrotus mammillatus* and *Echinometra mathaei*. These normally feed on algal films on the corals and, if competition for food is intense, the coral and its spat may be damaged. The increase in urchin numbers was thought to be partly due to a decline in population density of their predators, the large triggerfishes *Pseudobalistes fuscus* and *Balistes viridescens* and large pufferfishes *Arothron hispidus* and *Diodon histrix*, to about 5% of that observed previously on healthy reefs in the Red Sea. They are not commercial species but are caught by fishermen with handlines, the triggerfish for food, and more recently, in large numbers, for the souvenir trade (pufferfishes are inflated and sold as lampshades, and triggerfish are prepared and mounted) (Ormond, 1981). Several reefs off Sinai and the mainland have been damaged directly by spearfishing and souvenir collecting (TMRU, 1983). SCUBA diving and the use of the coast for recreation are becoming popular with Egyptians, and the number of overseas visitors is increasing. Following the reversion of the Sinai Peninsula to Egypt there were many reports of netting, dynamiting, lobster catching and spearfishing, the latter largely by foreign tourists (Bruun, 1983a; Matthews, 1982; *see Ras Muhammad account*).

The impact of oil pollution on the Egyptian Gulf of Suez and Red Sea coast has been studied by Awad *et al.* (1982), Frazier and Salas (1982), Hanna (1982 and 1983), Heathcote *et al.* (1984) and has been the subject of extensive research by the Oil Pollution Research Unit, U.K. (OPRU, 1980, 1983a, b, c, 1985). Reports on the subject have also been produced by the International Marine Consultative Organisation (IMCO) and the Institute of Oceanography and Fisheries (IOF, 1979-1981). From 1979 to 1980, oil pollution monitoring along the Sinai coast included surveys of areas with continuous oil spills, tar on the beach and hydrocarbons in the water. Two monitoring programmes were carried out along the east Sinai coast from Sharm el Sheikh to Taba (Shlesinger *in litt.*, 29.2.84).

Oil exploration in the Gulf of Suez and the construction of the Trans-Suez pipeline with a terminal at Ain Sukhna have given rise to increasingly severe pollution (Beltagy, 1976; Ormond, 1981). As well as being a major cause of reef deterioration, oil may affect the breeding of commercial fishes (Ormond, 1981). The main sources are the offshore oilfields in the central Gulf of Suez at Ras Gharib and Ras Shukheir (Hanna and Ormond, 1982; Ormond, 1981; TMRU, 1983), largely as a result of ineffective and inefficient operation of equipment, illegal discharge of dirty ballast water from tankers and lack of supervision and prosecution of offenders. Oil exploitation is expanding and there is therefore an increased likelihood of spills. An additional problem is the use of seismic explosions during exploration which damage the reefs (Frazier and Salas, 1982; Hanna, 1983).

In March and April 1982 there were two major oil spills, one of which amounted to 25 000 tonnes at Ras Shukheir (Matthews, 1982; TMRU, 1983). Studies between 1979 and 1981 indicated highest concentrations of dissolved hydrocarbon at Ras Gharib, Ras Shukheir and Ghubbet el Zeit. Minimum concentrations were recorded at Hurghada which may protected from the prevailing southerly current which presumably carries the oil with it by headlands (Hanna, 1982 and 1983). Pollution was also high at Safaga and Quseir. Bands of tar and thick accumulations of tar balls occurred along much of the Gulf's shore in the 1970s (Wennink and Nelson-Smith, 1979) and a band of tar 5-7 cm thick and several metres across was found on the shore at the mouth of the Gulf, at El Tur (Tor) and Ras Garra (Ormond, 1981). In the early 1908s, pollution had eased in the Hurgada and Quseir areas in the early 1980s, where there were only a few badly affected areas, partly as a result of active cleaning of some beaches (Barratt, 1982). Some 50 vessels pass through the Suez Canal daily, contributing to the problem through bilge pumping and garbage dumping (Frazier and Salas, 1982). The impact of the oil industry at two sites in the Gulf of Suez has been studied by OPRU (1980) and Dicks (1983). At Ras Budran, an environmental impact statement was used in the planning and construction phases which kept damage to a minimum; a survey in 1983 showed no oil impact except immediately around the offshore platforms from oil-based mud discharges (OPRU, 1983a). At Ras Gharib, pollution has been occurring over a period of about 50 years, and shallow reefs have been severely damaged although deeper reefs have not been too badly affected (OPRU, 1983b). In general, studies by the Oil Pollution Research Unit have shown that, apart from sites subjected to long-term pollution, corals are affected less by oil than shores, mangroves and seagrass beds.

**Legislation and Management**

Preliminary pollution abatement legislation was passed in 1962 and a new water pollution prevention law was enacted in 1983 (El-Ibyary, 1982). There is a strong support from ALECSO (Arab League Educational, Cultural and Scientific Organisation) and Unesco/UNDP have provided funds for further studies on aquatic and environmental pollution protection. Throughout the mainland Red Sea province and on the Sinai coast to the south of El Tur, the collection of corals, shells and other marine animals is forbidden and spearfishing or the taking of reef fish is reportedly prohibited (Myers, 1981).

A Northern Red Sea Resource Project was formed to set up marine parks for Egypt, Israel and Jordan in the early 1980s (Clark and Vanderbilt, 1982) but current activities under this programme are not known. In 1983, Egyptian Conservation Law No. 102 set up the legislative framework for the creation of protectorates. Prime Ministerial Decree 1067 of 1983 provides for the implementation of some of the provisions of Law 102. Details of current activities with respect to reefs were not known at the time of going to press but there are two protected areas which include coral reefs (*see separate accounts*):

- Ras Muhammad Marine National Park (includes Tiran and Sinafir Natural Reserves)
- Gebel Elba Conservation Area

Efforts to protect and manage the reefs are been largely limited to the Sinai Peninsula, where coastal nature reserves were established under Israeli occupation. With its reversion to Egypt, several organisations have been involved. In 1981 a brochure about the reefs was produced for visitors by the Egyptian Ministry of Tourism. Friends of the Red Sea have produced a pamphlet describing legislation of relevance to divers (Myers, 1981). The Sinai Conservation Group, a voluntary international organisation set up to promote conservation efforts in the Sinai, has also been involved. The MFO (Multinational Force and Observers) has its own conservation programme on Sinai.

A number of decrees cover the Sinai Peninsula specifically. Decree 15 of 1980 of the South Sinai Governorate prohibits fishing and the removal of species from reefs from Ras Muhammad to Taba on the Israeli border, in the east, and to El Tur on the Gulf of Suez to the west. Hunting and fishing may be permitted under certain conditions set by the administration. Violations are subject to imprisonment for 6 months to 2 years and fines of up to LE £500. Decree No. 472 of April 1982 prohibits hunting in certain parts of Sinai and the taking of fish (including shells, oysters, corals and other marine creatures) by nets or dynamite in the Gulf of Aqaba from

Taba to Ras Muhammad. The Egyptian Wildlife Service was given responsibility for enforcing these regulations.

**Recommendations**

A more formal legislative framework for protection of marine resources is required, as well as the development of an effective force of wardens. The U.S. Fish and Wildlife Service proposed a training programme for natural resource managers in the Sinai, particularly at Ras Muhammad (Bruun, 1983a; USFWS, n.d.) but it is not known if this was ever followed up. The Department of Conservation, the Institute of Oceanography and Fisheries or the Suez Canal University laboratory at Sharm el Sheik, should promote a programme of public awareness of the importance of the Red Sea for local people.

It is hoped that the creation of an Egyptian Environmental Affairs Agency will lead to measures enforcing and strengthening the new pollution prevention legislation, particularly that relating to oil activities in the Gulf of Suez. Recommendations of the IMCO report, to establish several units to prevent or clear up oil-spills, should be followed up. Oil companies must be persuaded to control pollution coming from installations in the Gulf of Suez as this is threatening the development of tourism and the health of fisheries and wildlife. Discharge of sewage and waste into coastal waters should be prohibited; disposal on land, and its use as a fertilizer, should be considered.

Large species of triggerfish and pufferfish should be completely protected under local regulations, and catching them, processing them as souvenirs and offering them for sale should be prohibited. It may be appropriate to licence a limited number of fishermen and traders to obtain and sell corals and shells collected from specific areas. The number of licensed purse seine fishermen should be reduced (Shaheen *et al.*, 1982). Possession or use of spearguns should be prohibited unless a special licence has been granted. Ferguson (1982) provides additional general recommendations.

Reefs along the west coast of the Sinai Peninsula recommended by Fishelson (1980) as worthy of protection include reefs south of El Tur, at Sheikh Raikh, the outer reefs of Ras Garra (*see separate account*) and some in the Strait of Gubal. On the east coast, Dahab and Nabq (Shlesinger *in litt.*, Dec. 1986) and Ras Burkha (*see separate account*) have been recommended for protection. Some sandy bays where turtles nest should also be protected. In 1981, parts of the eastern Sinai coast were recommended as protected areas by an IUCN resolution at the 15th IUCN General Assembly, and were recommended as World Heritage Sites. Following a project sponsored by IUCN and ALECSO to identify potential protected areas, the Tropical Marine Research Unit (TMRU), U.K., made the following proposals (TMRU, 1983) (*see separate accounts*):

- Shadwan Marine Park
- Hurghada Marine Biological Station Reserve
- Hurghada National Park
- Giftun Islands Marine Park
- Southern Egypt Marine Park

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## GEBEL ELBA CONSERVATION AREA

**Geographical Location** Southern Red Sea coast, including the island groups of Siyal off Adal Deib and Rawabel off Abu Naam, north to Shalatein, south to 22°N, and west to 36°E. The area is 290 km from Port Sudan and 520 km from Quseir, the nearest Egyptian town.

**Area, Depth, Altitude** About 4800 sq. km.

**Land Tenure** The Conservation Area lies in the Sudan Government Administration Area (SGAA), which may be considered Sudanese territory or Egyptian territory under partial administration by the Sudanese Government.

**Physical Features** Gebel Elba and other mountains in this area drain eastwards to the Red Sea through gently sloping plains. The area is remarkable for the unusual amounts of rain that it receives, mainly in winter. The terrestrial part of the Conservation Area is described in Goodman (1985). There is little information on the coastal and marine environment. There are a number of offshore islands forming the Siyal and Rawabel groups.

**Reef Structure and Corals** There are extensive fringing reefs along much of the coast.

**Noteworthy Fauna and Flora** The offshore islands are important for seabirds and turtles. Hawksbill *Eretmochelys imbricata*, Green *Chelonia mydas* and Leatherback *Dermochelys coriacea* Turtles nest on Gezira Siyal Kebir. Dugong *Dugong dugon* may occur. Patches of mangrove are found south of Shalatein. Details of the terrestrial fauna and flora are given in Goodman (1985).

**Scientific Importance and Research** A preliminary survey of the terrestrial part of the Conservation Area has been carried out (Goodman, 1985) but there has been no work on the marine environment.

**Economic Value and Social Benefits** There are a number of Bedouin tribes in the area, the most important being the Bischarin. Many of the latter have recently moved to coastal settlements under an Egyptian government programme. A small but apparently prosperous artisanal fishery exists (Goodman, 1985).

**Disturbance or Deficiencies** There was no evidence of significant oil pollution along the coast in 1983 and the fishing industry has little impact (Goodman, 1985). Threats to the terrestrial part are described in Goodman (1985). There is concern that the new coastal road could have a deleterious impact through accelerated development of the area.

**Legal Protection** Under Egyptian law, Decree 701 calls for establishment of the Gebel Elba region as a protected area. In 1984, Sudan agreed to cooperate and it was established under Prime Ministerial Decree No. 450 on 22.4.1986. The protected area includes the offshore islands and coastal mangrove stands, and the Abraq, El Deib and Gebel Elba areas.

**Management** The Decree setting up the park mandates that a branch of the Egyptian Environmental Affairs Division be established for implementing the articles of the decree. It is proposed that the administrative centre should be at Abu Ramad and draft regulations are given in Goodman (1985).

**Recommendations** Goodman (1985) recommends that priority should be given to managing Gebel Elba, the coastal mangroves between Shalatein and Halaib, and the Siyal and Rawabel island groups. The Conservation Area should be developed using a variety of management strategies, one of the objectives being to allow the Bischarin to continue their traditional life style. A more detailed survey is required, particularly of the coastal and marine environments, offshore islands and key species such as turtle, Dugong and birds. ALECSO is considering supporting further work in this area (Nasr, 1985).

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## GIFTUN ISLANDS PROPOSED MARINE PARK

**Geographical Location** Red Sea; the area would include the islands of Giftun el Seghir, Abu Ramada, Umm Agawish el Kebir, the southern part of Giftun el Kebir and the mangroves on Abu Minqar (Ormond, 1981) and could be included within the area of the proposed Hurghada National Park; 27°12'N, 33°57'E.

**Physical Features** The coast around most of the islands has small overhanging cliffs, about 1 m high. The reefs off Giftun el Seghir and Abu Ramada are adjacent to water over 100 m deep and are usually exposed to heavy wave action on the seaward side. Umm Agawish el Kebir is a low lying sandy island with extensive seagrass beds or complexes of seagrass, sand and coral knolls except on the sheltered western side where there is a fringing reef (Edwards *et al.*, 1981; Ormond, 1981).

**Reef Structure and Corals** Giftun el Seghir has precipitous reefs on the east coast. In the south-east the reef flat slopes to a 50 m wide sandy shelf at 20 m depth and then drops gradually to 50 m depth. *Acropora* is dominant and *Favia stelligera* is abundant. Massive *Porites* columns and *Millepora* fans are found on the initial drop-off. At 20 m and deeper, large *Acropora* tables, some 5 m in diameter, are found (Edwards *et al.*, 1981; Ormond, 1981). On the south of the island certain areas of the drop-off have a high density of soft corals, mainly *Dendronephthya* (Barratt, 1982). The fore-reef to the north of Giftun el Seghir has profuse coral growth down to 10 m and the back-reef has moderate coral growth down to 5 m, the base of both reefs finishing in sand. Dominant corals are *Millepora, Acropora, Stylophora, Pocillopora* and *Seriatopora* and coral cover ranged from 50 to 80% (Barratt, 1982; Ormond, 1981). Between the Giftun Islands there is a shallow varied reef in 4-5 m of water, the outer reefs dropping to approximately 40 m. Umm Agawish el Kebir is fringed on the west by a reef about 50 m wide which slopes steeply in places to 10 m depth and gently in others to 15 m depth. The reef flat consists of algal turf on coral rock and coral rubble. *Stylophora pistillata* is particularly abundant and small *Acropora* colonies were found on the reef edge as well as dead or dying *Porites, Stylophora, Pocillopora* and *Acropora* (Barratt, 1982; Edwards *et al.*, 1981; Ormond, 1981). On the other sides of the island, there are numerous patchy corals down to 6 m depth on a gently sloping sandy bottom. Abu Minqar has a sandy bed extending towards Merlin Point, with coral knolls covered with hard and soft (mainly *Litophyton*) corals (Barratt, 1982; Edwards *et al.*, 1981).

**Noteworthy Fauna and Flora** The sandy beach on the south-east coast of Giftun el Kebir is one of the three major nesting sites in the area for Hawksbill Turtles *Eretmochelys imbricata*. Large colonies of seabirds are also found there (Barratt, 1982; Ormond 1981). White-tip Reef Sharks *Triaenodon obesus* have been recorded off the south and Butterfly fish *Chaetodon* spp. were particularly abundant in the north (Barratt, 1982). There is an extensive monospecific stand of mangroves *Avicennia marina* between the two Abu Minqar islands which is one of the largest on the Egyptian coast (Barratt, 1982; Edwards *et al.*, 1981).

**Scientific Importance and Research** The islands have been visited by a number of expeditions including the U.K. Joint Services Expedition to the Egyptian Red Sea (Barratt, 1982), the Cambridge Red Sea Reef Study 1981 (Edwards *et al.*, 1981) and the Reefwatch Egypt 1982 Expedition (Gubbay and Rosenthal, 1982).

**Economic Value and Social Benefits** The Giftun Islands are the most important diving and snorkelling site on the main Red Sea coast, the Sheraton Hotel and the Club Mediterranée Muguwish Tourist Village being situated on the coast opposite them. There are many excellent diving sites, notably the seaward facing side of Giftun el Seghir which is already visited by tourists from the Mugawish Tourist village (on average 2-3 boats a day), and Umm Agawish el Kebir. A great attraction is the tameness of the fish (Edwards *et al.*, 1981). The shallow reef area between Giftun el Seghir and Giftun el Kebir and the coral fringe around Umm Agawish el Kebir are particularly suitable for snorkelling. The northern part of Giftun el Kebir and part of Abu Minqar are used extensively by local fishermen and are not considered for inclusion in the marine park (Ormond, 1981).

**Disturbance or Deficiencies** Anchor damage by tourist boats is noticeable on the Giftun reefs, with thickets of bush and staghorn *Acropora* corals broken and smashed in some places. The reefs show signs of intensive fishing, probably spearfishing, with very few reasonably sized edible fish, in particular coral trout and groupers (Serranidae) (Ormond, 1981). Oil pollution was reported to be heavy in 1981, and tar was found along the strand line and intertidal of the north-east shore of Umm Agawish el Kebir (Edwards *et al.*, 1981). In 1982 pollution was most noticeable on the windward or north-east facing shores where thick bands of tar, approximately 1.5 m wide and 1-2 cm deep, were found in intertidal regions, probably a result of the spill earlier that year. Severe pollution was found in the Abu Minqar mangroves, and although the mangroves seemed to be unaffected, it is very likely that the associated intertidal flora and fauna will have suffered damage. The leeward beaches were relatively unaffected, although tar-balls could be seen at all these sites (Barratt, 1982). The reefs and mangroves were also briefly surveyed following a tanker spill in 1985 (Dicks *in litt.*, 10.2.87). Thousands of tin cans left by military personel were found on Giftun el Seghir in 1981 (Edwards *et al.*, 1981).

**Legal Protection** Local regulations prohibit coral and shell collecting and spearfishing (Ormond, 1981).

**Management** None.

**Recommendations** It has been strongly recommended that this area be declared a park, tourist and recreational centre. Further protection will be required to control anchor damage, commercial fishing, fishing by the crews of tourist boats, coral collection for the souvenir trade, and disturbance of the seabird colonies and nesting turtles. It is suggested that the Park headquarters could be placed near the Muguwish Tourist Village. Permanent moorings and wardens would be required. Detailed recommendations for management of the proposed marine park are given in Ormond (1981).

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## HURGHADA (AL GHARDAQA) MARINE BIOLOGICAL STATION PROPOSED RESERVE

**Geographical Location** The area around Abu Sha'r Bay (27°17'N, 33°46'E), including Sha'b Abu Sadaf and Crescent Reef; the offshore reefs at El Fanadir Islands, Sha'b el Fanadir and Sha'b Abu Qalawa have been included in this account.

**Physical Features** Most of the reefs are shallow and sandy with limited coral growth. Visibility is poor due to the sandy conditions (Ormond, 1981). Sha'b Abu Sadaf reef, less than 1 km from the Marine Station, is surrounded by a sandy seabed (2 m deep) which slopes gently and is dotted with coral knolls (Edwards *et al.*, 1981). An attractive patch reef, rising from about 20 m depth to within approximately 2 m of the surface is found in the bay, about 200 m landward of Sha'b el Fanadir. Crescent Reef lies between Sha'b Abu Sadaf and Hurghada (Al Ghardaqa) about 140 m off shore, and is a hump-shaped reef, 40 m wide on a sandy bottom in about 5-7 m of water (Edwards *et al.*, 1981; Gubbay and Rosenthal, 1982).

The El Fanadir Islands, Sha'ab el Fanadir and associated scattered patch reefs lie to the east of Abu Sha'r Bay. The main fringing reef of the islands drops spectacularly to 75 m depth in places, but elsewhere drops vertically to a 40 m wide ledge at 15 m depth and then to 75 m depth; Barratt (1982) recorded a plateau at 10-20 m depth. The reef flat is close to the surface. A patch reef (150 m x 150 m) is separated from the main reef by a 7 m deep, 25 m wide sandy channel dotted with coral knolls, coral rubble and live coral stands. There are reef flats to the south of the islands (Edwards *et al.*, 1981; Gubbay and Rosenthal, 1982). Sha'ab Abu Qalawa is situated just outside Abu Sha'r Bay, north of Sha'b el Fanadir. Sediments of the intertidal zone in this area are described by El-Sayed and Hosny (1980).

**Reef Structure and Corals** Despite the sandy conditions, there is very high coral cover in some areas (Ormond, 1981). Dominant corals on Sha'b Abu Sadaf are *Acropora, Stylophora pistillata* and *Pocillopora*, and hard coral cover is 53%. Other corals present are *Favia, Goniastrea, Galaxea, Fungia* and *Herpolitha* with limited colonies of *Millepora dichotoma* and *M. platyphyla* on the coral knolls. Towards the centre of the reef flat the soft corals *Xenia* and *Litophyton arboreum* become increasingly common (Edwards *et al.*, 1981; Gubbay and Rosenthal, 1982). On the lagoon side of the reef flat, live coral cover is less than 20%. The reef on the north-east margin of Abu Sha'r Bay is similar (Gubbay and Rosenthal, 1982). The patch reef in the bay is dominated by *Acropora*, and has a live coral cover of about 80%, thirteen species of hard coral having been recorded (Edwards *et al.*, 1981). On Crescent Reef the main reef builder is *Galaxea fascularis*; other coral species include *Platygyra, Favia, Cyphastrea* and four or five species of *Acropora* (Edwards *et al.*, 1981; Ormond, 1981). The reef community is considered comparatively poor, with 25% hard coral cover and 22% soft coral cover (Edwards *et al.*, 1981; Gubbay and Rosenthal, 1982).

On the main fringing reef of the El Fanadir islands, mixed stony corals, gorgonians, soft corals, large *Millepora dichotoma* colonies, and sea-whips are common. In deeper water (55-65 m) black coral Antipatharia occurs. The patch reef to the north is characterized by dense *Acropora* stands, *Litophyton arboreum, Turbinaria, Millepora* and *Stylophora*. On the reef flats to the south of the islands *Stylophora* dominates and *Acropora, Goniastrea, Favia, Favites* and *Fungia* also occur (Edwards *et al.*, 1981, Gubbay and Rosenthal, 1982). Barratt (1982) recorded that the initial 5 m comprised steeply shelving fossil coral with a particularly attractive reef flat and an abundant and diverse fish fauna. This gave way to a sandy slope with few corals, mainly *Acropora* tables and massive forms. This became much steeper after 20 m depth and coral variation decreased below 30 m depth. Giant *Dendrophyllia*, with large fan-like structures, were dominant.

**Noteworthy Fauna and Flora** Hawksbill Turtles *Eretmochelys imbricata* have been observed in Abu Sha'r Bay and off the El Fanadir islands and Sha'ab el Fanadir (Barratt, 1982; Edwards *et al.*, 1981; Gubbay and Rosenthal, 1982). Black coral Antipatharia is found at the latter sites (Edwards *et al.*, 1981).

**Scientific Importance and Research** Mariculture and other aspects of marine biology are studied at the Marine Station which was established in 1931. A brief description of the station is given in Thompson (1983). There is a collection of local fauna and flora in the Museum (Beltagy, 1976). Research into oil pollution is being carried out by the Institute of Oceanography and Fisheries of the Egyptian Academy of Scientific Research and Technology in conjunction with the U.S. Environmental Protection Agency (EPA) (Walsh, 1982). The area has been surveyed by the Joint Services Expedition 1982 (Barratt, 1982), the Cambridge Red Sea Reef Study 1981 (Edwards *et al.*, 1981) and the Egypt Reefwatch 1982 expedition (Gubbay and Rosenthal, 1982). Hodgson (1982) studied reef community structure in this area. Work has also been carried out in the area by the Department of Oceanography at Alexandria University (El-Wakeel *et al.*, 1984).

**Economic Value and Social Benefits** Sha'ab el Fanadir with its spectacular drop-off is a particularly popular site for divers from the Muguwish village (Edwards *et al.*, 1981; Ormond, 1981). The El Fanadir islands are used by local people for fishing and shell collecting (Gubbay and Rosenthal, 1982).

**Disturbance or Deficiencies** In Abu Sha'r Bay, fish variety is limited, particularly around the Marine Station where there are few fish, high urchin densities (mainly *Diadema setosum*), poor coral cover, and high sedimentation. High densities of *Diadema setosum* were recorded in some areas. Crescent Reef and other areas in Abu Shar Bay suffered particularly severe damage from urchin grazing (Barratt, 1982; Gubbay and Rosenthal, 1982; Ormond, 1981). Litter was found in this area (Frazier and Salas, 1982). Edwards *et al.* (1981) found tar along the shore line of Abu Sha'r Bay and severe beach oil and tar were found at the Marine Station (Barratt, 1982). Collecting of shells and fishing may be causing damage at El Fanadir (Edwards *et al.*, 1981).

**Legal Protection** None.

**Management** The Marine Station regulated tourist activity on nearby reefs and limited fishing in the 1970s (Beltagy, 1976).

**Recommendations** It was suggested that a small marine reserve be established to protect an area for scientific study and limited recreational and tourist use (Ormond, 1980a). This could lie within the proposed Hurghada National Park and the park headquarters could be sited at the laboratory (Ormond, 1981).

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## HURGHADA PROPOSED NATIONAL PARK

**Geographical Location** Northern Red Sea. The proposed area would include the reefs around and to the east of the Hurghada Marine Biological Station; the El Fanadir islands (27°17'N, 33°50'E) and the small scattered islands and reefs to the north-east (Sha'b el-Erg 27°24'N, 33°51'E, Sha'b Abu Nigara 27°21'N, 30°50'E, and Umm Qamar Island 27°21'N, 33°59'E); the Giftun Islands and Abu Minqar Island (27°11'N, 33°50'E) opposite Hurghada; Umm Agawish el Kebir Island to the south (27°09'N, 33°52'E); the fringing reefs off the mainland including Sheraton Reef (27°11'N, 33°51'E), Merlin Point (27°12'N, 33°51'E) and Disha el Dab'a (27°05'N, 33°52'E), 18 km south of Hurghada; and the two islands of Abu Minqar opposite Merlin Point. The proposed Giftun Marine Park and the Marine Biological Station Reserve (*see separate accounts*) would lie within this area. This account describes the fringing reefs and north-east reef complexes.

**Physical Features** The mainland fringing reefs consist of an extensive series of shallow reefs bordered by a gently sloping sandy sea-bed, typically within 5 km of the coast. Visibility is limited in places. Merlin Point is a rocky shore to the north of the Hurghada Sheraton Hotel, with a fringing reef which drops to sloping sand at 1.5 m depth. This continues for 30-50 m to a seagrass bed, 20-30 m across at 6-7 m depth which slopes to 10 m depth where there is coral substrate with patches of sand (Edwards *et al.*, 1981; Gubbay and Rosenthal, 1982). The Sheraton Reef lies 1 km off shore just south of the Sheraton Hotel in Umm Agawish el Kebir Bay. It has a reef flat (1-2 m deep) and a well defined reef edge dropping to a gently sloping sandy seabed at 2-20 m depth (Barratt, 1982; Edwards *et al.*, 1981). Immediately adjacent to the hotel, the Sheraton Beach slopes down to a large dense seagrass bed (Edwards *et al.*, 1981; Gubbay and Rosenthal, 1982). At Disha el Dab'a, the fringing reef on the south of Umm Agawish el Kebir Bay borders a wide (300-800 m) lagoon which is partly sandy, partly flat rock, partly seagrass. A heavily sculptured 50 m wide reef flat slopes rapidly to gently shelving sand at 7 m. This continues for 100 m to sparsely dotted clumps of corals at 10 m depth and a flat seagrass plain at 12 m (Edwards *et al.*, 1981).

Sha'b el Erg is a reef complex, 16 km off shore, with patch reefs on the western tip. There is a broad reef flat, 70-100 m wide, falling to a sandy lagoon at 5 m depth on the inside and to 15 m depth on the outside, where there is a steep drop-off with a ledge at 10 m depth. Sha'ab abu Nigara, situated between Sha'b el Erg and the coast, has a very gently sloping reef to a depth of 17 m with a sandy lagoon on the inside at 4 m depth. The Umm Qamar reef system lies 15 km off shore to the north-east of the Marine Station. An island at the southern tip of the complex is bordered by a fringing reef (Gubbay and Rosenthal, 1982).

**Reef Structure and Corals** At Merlin Point the fringing reef and coral outcrops are dominated by *Acropora*. Other fairly common corals include *Seriatopora, Favia, Goniastrea, Millepora dichotoma* in isolated patches and the Alcyonacea *Xenia, Sarcophyton, Litophyton* and *Dendronephthya* (Edwards *et al.*, 1981; Gubbay and Rosenthal, 1982). Sheraton Reef is also dominated by *Acropora* (Barratt, 1982; Edwards *et al.*, 1981). At Disha el Dab'a, the reef has scattered colonies of *Stylophora pistillata* (Barratt, 1982; Edwards *et al.*, 1981), with coral cover varying from 5 to 70% at 1.5 m depth and dropping to 10% at 10 m depth, perhaps as a result of dynamiting (Barratt, 1982).

Sha'b el Erg has high coral and algal cover on the reef flat, but little on the inner reef face except some large mounds of *Goniopora*. Dominant corals include *Acropora* especially *A. eurystema*, and on the reef flat *A. corymbosa, Leptoria, Goniastrea, Favia stelligera* and *Millepora dichotoma* (Gubbay and Rosenthal, 1982; Ormond, 1981). At Sha'b Abu Nigara the outer slope is cavernous and heavily eroded with moderate coral cover. Common corals include *Echinopora lamellosa, Hydnophora micronos* and *H. excesa*. *Acropora* tables and *Porites* mounds occur on the sandy bed. Coral cover on the reef edge is poor (Gubbay and Rosenthal, 1982; Ormond, 1981). The part of Umm Qamar which has been surveyed has a 60 m wide reef flat with a rich algal turf community, colonies of *Stylophora* and isolated heads of *Pocillopora*. This is followed by a steep drop to 40 m depth, although in some areas there is a ledge at 3 m depth and a more gradual slope. The fringing reef community is rich with prolific corals in the top 10 m of the reef face including *Acropora, Platygyra, Favites, Goniastrea* and *Fungia* (Gubbay and Rosenthal, 1982).

**Noteworthy Fauna and Flora** The Hurghada Islands are an important nesting area for seabirds and turtles (Ormond, 1981). The seagrass beds in the region of the

Sheraton Beach at Hurgada are considered to be some of the best in the area, containing at least five species (Barratt, 1982); the seagrass beds at Disha el Dab'a are predominantly *Halophila stipulacea*. Merlin Point has a rich fish community but Sheraton Beach and Reef have a comparatively poor fish fauna, although pufferfish (Tetraodontidae) have been recorded (Edwards *et al.*, 1981; Gubbay and Rosenthal, 1982). Giant Clams *Tridacna* spp., Spider Conchs *Lambis* spp., Pufferfish *Arothron diadematus* and Black Tip Reef Shark *Carcharhinus melanopterus* have been recorded in the area (Barratt, 1982; Edwards *et al.*, 1981). Fish in the Hurghada region are described by Abel (1960).

**Scientific Importance and Research** Surveys of the reefs in this area include those by the Cambridge Red Sea Reef Study 1981 (Edwards *et al.*, 1981), the Reefwatch Egypt 1982 Expedition (Gubbay and Rosenthal, 1982), and the Joint Services Expedition (Barratt, 1982). Studies on three genera of Serranidae have been conducted by Ghorab *et al.* (1982) and on interactions between alcyonarians and stony corals by (Hodgson, 1982).

**Economic Value and Social Benefits** Hurghada is the main tourist development on the Egyptian Red Sea coast, and has large numbers of visitors, many coming principally for the diving and snorkelling. The creation of a national park would undoubtedly increase the income derived from this. Among the many good dive sites, the Sheraton Reef is a picturesque and ideal introductory site for novice divers (Edwards *et al.*, 1981); the Sheraton Hotel and Club Mediterrée are major diving centres. There is a thriving souvenir trade in locally collected cowries, giant clams, staghorn coral, pufferfish, stuffed sharks, turtles and dugongs. *Lambis lambis* and *Murex* sp. are collected by local people for food (Edwards *et al.*, 1981).

**Disturbance or Deficiencies** Oil pollution is a potentially severe problem. The nearest areas of oil exploration are in the Ras Gemsa region about 50 km north of the Marine Biological Station. In 1981, pollution in the Hurghada area was found to be very variable from site to site, the complex of offshore reefs and islands presumably protecting some sites from slicks drifting ashore (Edwards *et al.*, 1981). Analysis of dissolved hydrocarbons in seawater and tar ball estimates along the north Egyptian Red Sea coast, showed that Hurghada had the lowest concentrations, possibly because of protection provided by projecting headlands and islands (Hanna, 1983). However, analysis of dominant littoral organisms for hydrocarbon content revealed highest concentrations in those organisms sampled at Hurghada (Awad *et al.*, 1982).

In 1981, many areas had deep bands of oil on the beach in the intertidal zone and tar mats at the strand line as well as considerable litter. Extensive tar was found along the shore at Merlin Point, although it is considered that this may have been a relic of oil pollution from more than 25 years ago (Edwards *et al.*, 1981). Pollution did not seem to be a problem at the Sheraton Beach in 1982, possibly because the beach is actively cleared for tourists (Barratt, 1982), although in 1981 there were small amounts of tar and much newspaper litter on the seabed in shallow water (Edwards *et al.*, 1981). At Disha el Dab'a, extensive litter, tar-balls and tar were recorded on the strand line and beaches (Barratt, 1982; Edwards *et al.*, 1981).

In 1982 fresh oil was found on the water surface especially on rocky shores, cliffs and beaches. Many organisms had been contaminated or killed by oil including algae *Padina* and *Halimeda*, the angiosperms *Halophila* and *Halodule*, crabs, Hawksbill Turtles *Eretmochelys imbricata*, White Stork *Cicona alba*, Spoonbill *Platalea leucorodia* and Osprey *Pandion haliaetus* (Frazier and Salas, 1982). *Stylophora*, a common reef flat coral, was frequently found coated with oil (Ormond, 1981). The Hurghada reefs were briefly surveyed following a tanker spill in 1985 (Dicks *in litt.*, 10.2.87). There have been reports that fish catches have declined as a result of oil pollution and that the Club Mediterranée lost trade through pollution (Matthews, 1982). Seismic testing occurs in the course of oil exploration (Barratt, 1982; Frazier and Salas, 1982) but it is not known to what extent this has damaged reefs. Extensive litter has been found near the Marine Station and on the Sheraton Beach (Frazier and Salas, 1982; Gubbay and Rosenthal, 1982).

Considerable damage to the reefs at Sha'ab el Erg and Sha'ab Abu Nigara was caused by large numbers of the urchins *Diadema setosum, Heterocentrotus mammillatus* and *Echinometra matthaei*. These kill living corals by damaging spat while grazing on algae growing on the reef surface. Populations have increased due to a decrease in numbers of their predators: large triggerfish, *Pseudobalistes fuscus* and *Balistoides viridescens*, large pufferfish *Arothron hispidus* and porcupinefish *Diodon histrix*, which are popular in the souvenir trade. The population of these predators is only 5% of that previously observed. Oil pollution appeared to interfere with recolonization of damaged reefs, compounding the problem (Barratt, 1982).

There was evidence of dynamite fishing at a number of sites and spearfishing was intensive in some areas. Both were seen at Disha el Dab'a (Barratt, 1982). Sha'ab El Erg and Sha'ab Abu Nigara showed signs of intensive fishing; few large commercial species of fish, such as Serranidae, were seen, probably due to heavy fishing and spearfishing in the past by visiting tourists (Ormond, 1981). As the tourist industry develops, there could be serious depletion of some species. Edwards *et al.* (1981) list some of the commonest species sold, which include Common Spider Conch *Lambis lambis*, Giant Clams *Tridacna maxima*, the starfish *Pentaceraster mammillatus*, White-spotted Pufferfish *Arothron hispidus* and the Porcupinefish *Diodon hystrix* and report that the fringing reef at Disha el Dab'a is one of the collecting sites.

**Legal Protection** Dynamite fishing and spearfishing has been prohibited by the Red Sea Province Governorate (Ormond, 1981) (*see* "Introduction" for national legislation).

**Management** The Club Mediterranée at Muguwish and the Sheraton at Hurghada forbid collecting and spearfishing (TMRU, 1983).

**Recommendations** This whole area has been proposed as a National Park, with headquarters at the Marine Laboratory (Ormond, n.d.) but this recommendation has not been followed up. Further information is required on the souvenir trade in this area and it has been suggested that some form of quota system might be introduced to control collection without causing local people to lose their livelihoods (Edwards *et al.*, 1981).

## RAS BURKHA

**Geographical Location** East coast of Sinai peninsula on the Gulf of Aqaba, 50 km south of the Israeli border and 20 km north of Nuweiba; 29°05'N, 34°40'E.

**Physical Features** A prominent head of white sand. The fringing lagoonal reef encircles the point parallel to the shore (Cohen, 1975; Fishelson, 1980).

**Reef Structure and Corals** Fishelson (1980) gives a generalized description of "lagoonal" reefs similar to that at Ras Burkha. In the north, branching colonies predominate and coral cover is abundant. In the south there are large knolls mainly of *Porites*. The reef drops off to a sand and seagrass area at 8-10 m depth. There are numerous tunnels, caves and holes in the reef (Schlesinger *in litt.*, 1985).

**Noteworthy Fauna and Flora** No information.

**Scientific Importance and Research** No information.

**Economic Value and Social Benefits** It was a popular diving site when under Israeli control (Cohen, 1975).

**Disturbance or Deficiencies** No information.

**Legal Protection** None.

**Management** None.

**Recommendations** Proposed as a reserve by Fishelson (1980).

## RAS GARRA

**Geographical Location** Gulf of Suez, on the Sinai coast south of El Tur; 28°01'N, 33°45'E.

**Physical Features** A discontinuous fringing reef sloping to a seagrass bed, at 3-4 m depth in a lagoon (Ormond, 1981).

**Reef Structure and Corals** Coral cover is sometimes very high (30-80%) on the reef slope, which may have abundant soft coral and macroalgae. The main genera are *Galaxea, Platygyra* and *Acropora* (Ormond, 1981).

**Noteworthy Fauna and Flora** No information.

**Scientific Importance and Research** Surveyed briefly by Ormond (1981) but no details are given.

**Economic Value and Social Benefits** No information.

**Disturbance or Deficiencies** In 1972 the area was not inhabited but was heavily and continuously polluted by oil. Ninety per cent mortality of corals was recorded in 1974 (Rinkevich and Loya, 1977). A band of tar up to 5-7 cm thick and several metres across was found on shore in 1980 (Ormond, 1981).

**Legal Protection** None.

**Management** None.

**Recommendations** The outer reefs are worthy of protection (Fishelson, 1980).

## RAS MUHAMMAD MARINE NATIONAL PARK

**Geographical Location** The southernmost tip of the Sinai peninsula; northern boundary is the Sharm el Sheik to El Tur road; 27°44'N, 34°15'E.

**Area, Depth, Altitude** Approx. 66 sq. mi. (171 sq. km) with a 10 mi. (16 km) coastline; max. alt. 73 m.

**Physical Features** Low cliffs of raised fossil coral rise from the water in the east and in the west there is a clear creek with sandy shores, seagrass beds and a small mangrove stand. The high bluffs of Ras Muhammad (Ras Mohammed) itself are connected to the mainland by a narrow land bridge 3.5 km long and 1 km wide. The mainland area includes mountain habitat, such as Gebel Kharhabi, and is crossed by two wadis. The southern tip of the headland is an island separated from the head by a shallow channel filled with mangroves, much of it intertidal. The lagoon has very clear water and attractive seagrass beds, largely of *Cymodocea ciliata*. Exposed reefs are found adjacent to water over 100 m deep (Ormond, 1981). Due to the lack of run-off from the land there is good water clarity (Clark and Vanderbilt, 1982) with fast currents running in some places. Surface water temperatures range from 20° to 30°C and salinity is high.

**Reef Structure and Corals** The reef encircles the entire headland. A shallow reef flat ends in cliff-like drop-offs to ledges at 70 m and thence down to over 100 m depth (Clark and Vanderbilt, 1982). At the headland there is an extensive terrace at approximately 15 m depth. Off shore are a number of patch reefs. There is a high density and diversity of corals. Large stands of *Millepora* and *Acropora* dominate the reef edge with *Favia, Favites, Echinopora, Porites, Pocillopora, Fungia, Pavona* spp., *Podobacia crustacea, Gardineroseris* and *Dendrophyllia*. Coral cover averages 40-50% (Ormond, 1981).

**Noteworthy Fauna and Flora** There is a small stand of mangroves. Giant clams *Tridacna maxima* are common. Numerous large open-water fish such as Napoleon Wrasse *Cheilinus undulatus* visit the reefs and are remarkably tame. Sharks (Selachimorpha) are seen frequently. Sparse nesting of Green Turtles *Chelonia mydas* may occur (Groombridge, 1982). Dugong *Dugong dugon* have been reported (Abou Zeid pers. comm., January 1983). Ras Muhammad is an important ornithological site during spring and autumn migrations, particularly for White Storks *Ciconia ciconia* and birds of prey. Osprey *Pandion haliaetus* and Sooty Terns *Sterna fuscata* nest on the peninsula and herons (Ardeidae), Sooty Gulls *Larus hemprichii* and Brown Boobies *Sula leucogaster* are also seen. The Dorcas Gazelle *Gazella dorcas* was reported at Ras Nasrani on the mainland (Abou Zeid pers. comm., January 1983) (although the only published records of gazelle in the Sinai refer to the Mountain Gazelle *G. gazella*). Sand Foxes *Vulpes rueppelli* and Fennec *V. zerda* have also been reported.

**Economic Value and Social Benefits** The Bedouin have used the area for many centuries for fishing. The site is now a focus for tourism in the southern Sinai, because of its scenic location and internationally renowned diving sites (Cohen, 1975). Whilst under Israeli control an estimated 3000-5000 tourists visited Ras Muhammad each year (Rutstein, 1982). It is easily accessible by road and air and the Egyptians are promoting tourism, by improving hotel facilities and increasing publicity although the industry has not yet returned to the importance it had under Israeli occupation. There are several diving centres and, on average, 10-20 people dive on the reefs every day; the presence of a number of wrecks adds to its attraction. Cohen (1975) describes some of the popular dive sites. The area also has high educational potential with its differing and easily accessible habitats (Ormond, 1981).

**Disturbance or Deficiencies** The Bedouin occasionally take Giant Clams *Tridacna maxima* but their fishing activities have a negligible impact. (Excessive fishing, spearfishing and coral collection have been reported but not confirmed). Fishing is uncontrolled and dynamiting occasionally occurs. In 1982 it was reported that on average 20-30 fishing vessels a day operated in the deep waters beyond the reefs (Rutstein, 1982). Large quantities of lobsters are also taken. Spearfishing by foreign tourists is relatively widespread and difficult to prohibit (Frazier and Salas, 1982; Matthews, 1982; Rutstein, 1982). However, the area is largely free of development and visitor pressure is low owing to the heavy military presence (Ormond, 1981; Wells pers. obs., 1983). Excessive diving pressure could become a problem in the future, but dive boats tend to visit the same sites regularly where there are permanent moorings and most visiting divers are accompanied by guides. The mangrove inlet collects flotsam and jetsam and has been affected by oil (Matthews, 1982). Oil from the terminals further north in the Gulf of Suez represents a potential threat but Ras Muhammad's position in the vicinity of strong currents makes it less susceptible to pollution. Currently there is no enforcement of conservation decrees in the area and the Egyptian Wildlife Service responsible for this is severely under-staffed.

**Legal Protection** Declared a Marine Park, November 1983, under Prime Ministerial Decrees 1067 and 1068 in accordance with Law 102. Decree 1068 prohibits hunting, fishing, destroying or disturbing fauna or flora, introducing alien species, polluting, draining, anchoring ships except under conditions to be established, littering, or constructing roads or buildings without the permission of the Governorate's Environmental Affairs Agency. A clause within the legislation permits fishing and hunting under certain conditions which can be set by the administration. The decrees issued for Southern Sinai (*see* "Introduction") also apply.

**Management** There is no official management within the Park. Under Israeli rule the Marine Reserve at Ras Muhammad was strictly enforced by coastline wardens under the Israel Nature Reserves Authority. No collecting was allowed within the Reserve and any damage was punishable (Fishelson, 1980). Signs and footpaths were laid out in parts of the mainland area. Commercial fishing trawlers were prevented from approaching the reefs and overnight camping was prohibited, visits being limited to small groups in the day time (Rutstein, 1982). With the return of this area to Egypt, these regulations have been allowed to lapse. Dive guides insist on a policy of no collecting or spearfishing by visiting divers, and there is no sale of marine curios in the hotels at Sharm el Sheik. Spearfishing offences are reported to the police and a wildlife officer has been appointed. A U.K.-based international group, Friends of the Red Sea (FORS) have produced a pamphlet for visitors (Myers, 1981).

**Recommendations** A management plan was drawn up by the regional Wildlife Officer in 1983. The Park is to consist of a series of zones. The central isthmus, headland and bordering reefs is to be the "core" zone and treated as a strict nature reserve. Shark Bay will be the principal diving zone and diving will be monitored. Buffer zones on either side of the core zone will extend several kilometres east and west. The northern limit of all zones will be the Suez-Taba "highway", with the southern limit extending 1.5 km from the coastline into the Gulf. There will be an absolute prohibition on fishing in the buffer zones. A development zone in the west will be for camping and snorkelling and will have the headquarters of the local wardens. At present it is not possible to carry out this plan and an interim plan has been suggested by the Sinai Conservation Group, using existing conservation personnel, the local diving centres who are keen to help, and local police.

Detailed recommendations to deal with some of the terrestrial disturbances are given in Matthews (1982) and Frazier and Salas (1982). A detailed survey of the marine environment is a high priority. Plans have been drawn up to initiate a training scheme for wardens and staff but it is not known if this was implemented. It has been suggested that there should be six wardens, guards and administrative staff. Equipment, including a boat and telescopes will be required. The Park centre should include an interpretive centre, a field centre and a dive centre run by the Park. Adjacent sections of the Park could be used for commercial production of rabbitfish (Siganidae) and porgies (Sparidae) for export (Rutstein, 1982).

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## SHADWAN PROPOSED MARINE PARK

**Geographical Location** South of the entrance to the Gulf of Suez, opposite Gemsa and north of Hurghada. To include the islands of Gubal, Tawila, Siyul, Shadwan and Sha'ab Abu Shiban reef; approx. 29°-30°N.

**Physical Features** No information.

**Reef Structure and Corals** Gubal, Siyul and Shadwan have intermediate reefs with high coral cover adjacent to water over 15 m deep. At Tawila and Sha'ab Abu Shiban, there are shallow sandy areas where reef development is generally limited. Off Gubal Island the outer reef face drops irregularly to 7 m and then slopes to 20-30 m or more depth. The reef face has bays and alcoves with knolls on the slope. The inner reef forms attractive coral gardens in some areas. There is very high live coral cover. *Acropora* is dominant on the reef flat, and *Goniastrea, Favia stelligera, Echinopora* spp., *Favites, Porites*, and *Lobophyllia* are abundant on the reef front.

Off Tawila Island there are a few low mounds of coral and scattered coral heads at 2-3 m depth. The dominant corals are *Styllophora pistillata* and some *Acropora*. Off Siyul Island, the leeward reef slopes to 15 m depth, and is cavernous and eroded. The seaward reef slopes to about 22 m and is also eroded with less coral cover. Corals include *Acropora* spp., particularly on the reef flat, *Millepora platyphylla* on the outer reef crest and some *Favia* and *Goniastrea*.

At Shadwan Island, to the north-west, the reef slopes comparatively gently to depths of 15-20 m. There is high coral cover on the reef flat, but less on the slope. The dominant corals are tables and thickets of *Acropora* on the reef flat, *Platygyra* and *Favia*, and on the slope *Millepora* spp. and large areas of *Porites*. Sha'ab Abu Shiban reef has scattered large mounds on a sandy bottom at 2-4 m depth. There is good coral cover on some mounds, and the dominant species are *Acropora, Porites, Goniastrea, Favia* spp. including *F. stelligera, Platygyra* and *Echinopora gemmacea* (Ormond, 1981). A description of the reefs in this area is given in Fleissner and Fleissner (1971) and reefs around Gubal and Tawila have been surveyed by Dicks (1986), Dicks and Westwood (in press) and OPRU (1983c and 1985).

**Noteworthy Fauna and Flora** Gubal Island is one of the three nesting sites for Hawksbill Turtles *Eretmochelys imbricata* in the area. Shadwan is also an important turtle nesting site. Tawila Island has rich and varied seagrass beds with four species of seagrass and well developed seagrass beds are found between the reefs off Gubal. Many *Heterocentrotus mammillatus* were found at Siyul Island, and high numbers of *Echinometra mathaei* and *H. mammillatus* were recorded on the reef slope at Shadwan Island in the late 1970s. The Gubal Island reef had a high density of *Diadema setosum* (Ormond, 1981).

**Scientific Importance and Research** The islands were investigated by Ormond (1981) for the Institute of Oceanography and Fisheries. Shadwan is considered to be one of the finest reef sites in the area.

**Economic Value and Social Benefits** No information.

**Disturbance or Deficiencies** Considerable reef erosion from large populations of sea urchins, notably *D. setosum*, was recorded at Gubal, Siyul, Shadwan, and locally at Sha'ab Abu Shiban. There were correspondingly low populations of their predators, puffer (Triodontidae), trigger (Balistidae) and porcupine (Diodontidae) fish, which are being heavily fished for the tourist souvenir trade. Dynamiting had occured at Shadwan destroying patches of the reef (Ormond, 1981). Surveys following the development of an offshore oilfield showed that, despite damage to shores, mangroves and seagrass beds, there has been no oil-related coral damage (Dicks, 1986; Dicks and Westwood, in press; OPRU, 1985).

**Legal Protection** None.

**Management** For thirteen years the area has indirectly received protection through the presence of the military (Ormond, 1981).

**Recommendations** The area should be considered for protection (Ormond, 1980a and 1981), although the recent military significance of the area means that it will be sometime before it can become a major tourist site. Fischelson (1980) recommended the Strait of Gubal for marine reserve status.

## SOUTHERN EGYPT PROPOSED MARINE PARK

**Geographical Location** South of Hurghada (approx. 27°00'N, 33°00'E) to the Sudanese border (approx. 23°00'N, 35°30'E).

**Area, Depth, Altitude** Over 300 km of coastline.

**Physical Features** The area has fringing reefs with inlets, bays, offshore patch reefs and island reefs. In certain areas the reef flat is submerged giving rise to shallow lagoons. From Safaga south to Ras Banas there is continuous, often well-developed fringing reef but the continental shelf in this area is narrow and the seabed falls away rapidly preventing the formation of offshore reefs. Water salinity is high, and there is intense sunlight and high eutrophication of algae.

**Reef Structure and Corals** The reefs have been briefly surveyed at a number of sites by Barratt (1982), Gubbay and Rosenthal (1982) and Edwards *et al.* (1981).

At a site 5 km north of Hammarawein (26°16'N, 36°12'E), the reef flat is 50 m wide with patches of seagrass and the reef face drops steeply to a sandy bottom at 6 m depth which then slopes gradually to 18 m depth, 100 m from the reef face. Caves extend 10-15 m under the reef flat and there is a high hard coral cover.

South of Hammarawein (12 km north of Quseir, 26°11'N, 34°13'E), a reef flat extends into the first bay and is widely exposed at low tide. Water clarity is low in the bay, but improves at headlands. The seaward reef face drops steeply to 15 m depth and has caves. There is greater coral cover on the reef flat away from the headlands and in the south. Large tables of *Acropora* occur on the sandy bottom.

At Old Quseir (26°09'N, 34°14'E), in the second bay south of Hammarawein, there is a narrow gap in the fringing reef forming a deep water channel to shore. The reef flat on the north side of the bay drops to 20 m depth and on the south side to 12 m depth. Caves extend under the reef flat. On the north side of the bay *Millepora dichotoma, M. platyphylla* and *Acropora* tables are common. *Stylophora, Seriatopora* and *Porites* are found on the reef flat. On the south side soft corals are common, predominantly *Xenia*, with a high proportion of dead *Acropora*. *M. dichotoma, Porites, Podobacia* and *Pachyseris* also occur with some algal cover.

Sharm el Bahari, 30 km south of Quseir (25°51'N, 34°24'E), is a deep inlet with a fringing reef, 10 m wide at the mouth which gives way to mangroves on the northern shore and sand on the southern shore where the water is more turbid. *Stylophora pistillata* occurs on the reef flat. At the reef crest the soft corals *Litophyton* and *Sarcophyton* occur. Hard corals at the crest include *Porites, Seriatopora, Pocillopora, Turbinaria, Hydnophora, Favia,* and *Favites*. *Millepora dichotoma* and *M. platyphylla* are particularly common. Coral diversity is low, but is higher in the south (Edwards *et al.*, 1981; Gubbay and Rosenthal 1982).

At Marsa Umm Gheig (25°42'N, 34°33'E) there is a patch reef 100 m off shore, with a maximum depth of 20 m, a rugged reef face and a high percentage of coral cover. At Marsa Umm Gerifat, 65 km south of Quseir (25°36'N, 34°36'E), the reef flat on the north side extends 30 m within the bay and then drops to 25 m depth. There are overhangs, caves and passages, but heavy siltation.

Marsa Mubarak 75 km south of Quseir (25°31'N, 34°36'E) is a deep sheltered inlet with a fringing reef. The reef flat, dominated by macroalgae, is 200 m wide on the north side and 500 m wide flat on the south side, narrowing to 10 m towards the river mouth or wadi. It is exposed at low tide and drops to a sandy bottom with rocky outcrops which are more extensive towards the headlands where caves and caverns extend under the reef flat, particularly on the north side. Outside the inlet the reef face drops steeply to a sandy bottom with isolated rocks at 35 m depth. At the reef crest mounds of *Porites* and pillar like forms of *Montipora* dominate and *Millepora dichotoma* is very common. Coral cover is quite low. On the outer reef outside the marsa there is greater coral variety (Barratt, 1982; Edwards *et al.*, 1981; Gubbay and Rosenthal, 1982).

The fringing reef flat 2 km south of Marsa Imbarak (25°30'N, 34°40'E) has large boulders. A break in the reef forms a small sandy gully with high turbidity. The seaward reef face slopes to a terrace at 25 m depth and then drops steeply; on the reef face there is good coral cover dominated by columns of *Porites*.

The fringing reef 45 km north of Marsa Alam (25°25'N, 34°41'E) is 100 m wide and has caves extending under the reef flat, and sand gullies with notable downcurrents of water. Water clarity is poor. Large mounds, often 3 m high, of *Porites* occur and *Montipora, Xenia* and *Turbinaria* are common. The small bay 2 km further south (25°23'N, 34°41'E) has also poor water clarity and an outside reef face which drops vertically to 20 m depth before shelving gently. The fringing reef 38 km north of Marsa Alam (25°22'N, 34°44'E) has a small gap which forms a gully with scattered boulders on a sandy bottom, barren rock walls and low water clarity. Caves extend under the reef flat on the seaward face of the reef. A strong current runs over the reef flat and at the base of the outer reef face. To the north, water clarity improves, and there is an increase in hard coral cover. To the south of the gully the coral fauna is dominated by columns of *Porites* and *Xenia*. A small bay 3 km south of this (25°20'N, 34°41'E) has restricted reef development, with a reef face sloping gradually to 20 m depth where there are patches of rock on a sandy bottom which are mainly covered by *Xenia*.

A fringing reef with a small patch reef lies 100 m off shore, 26 km north of Marsa Alam (25°19'N, 34°47'E), with very high coral cover, a reef face which drops to 15 m depth, and the patch reef dropping to 30 m depth. The reef 9 km north of Marsa Alam, (25°07'N, 34°52'E), drops steeply to 25 m depth and then levels before dropping to a 20 m wide seagrass bed which borders the sandy bottom; there is reasonable coral variety and cover.

Marsa Alam Bay (25°04'N, 34°54'E) has a fringing reef which drops off steeply to a sandy shelf approximately 50 m wide, at 20 m depth, then drops steeply to over 55 m depth. There are surge channels full of coral rubble. Water visibility is 15-20 m. The bay extends into a short lagoon to the south. The reef edge consists of coral rock covered with algal turf and *Stylophora, Pocillopora, Acropora, Pachyseris* and *Millepora*. The lagoon side of the reef is predominantly algal turf on coral substrate with *Acropora* and *Stylophora* (Edwards *et al.*, 1981). Sweetlips Reef off Marsa Sifein is a circular patch reef, 30 m in diameter. The reef flat is submerged and the western landward face drops to a sandy bottom with scattered boulders at 22 m depth. Soft corals are particularly common, *Dendronephthya* dominating the western face and *Xenia* and *Sarcophyton* occurring on the reef flat and scattered boulders (Barratt, 1982). Sha'b Alam opposite Marsa Alam has a patch reef, 500 m long with a maximum diameter of 150 m, surrounded by deep water. The top 10 m of the reef are heavily sculptured with caves and crevices. Water visibility is 50 m and there are impressive but not diverse corals, especially a mass of *Porites* columns on the north face (Barratt, 1982; Edwards *et al.*, 1981). The islands opposite Wadi Gemal (24°29'N, 30°10'E), have sandy shores and mangroves (Barratt, 1982).

**Noteworthy Fauna and Flora** The offshore islands and mangroves provide important stopping points for migratory birds (Ormond, 1976). Gezirat Wadi Gemal has extensive areas of mangrove and is an important bird nesting site. Over 500 Sooty Gulls *Larus hemprichii* nest on the open sandy plains. The largest reported concentration of Sooty Falcons *Falco concolor* in the Red Sea nests in the mangroves. Ospreys *Pandion haliaetus* nest on the shoreline and in the mangroves (Barratt, 1982).

Dugongs *Dugong dugon* occur in small numbers and are decreasing. They are mostly caught during gill netting for shark and may be locally extinct (Ormond, 1976; Thornback and Jenkins, 1982). No turtle nesting sites are known but may exist on offshore islands (Ormond, 1976). Hawksbill Turtles *Eretmochelys imbricata* and Green Turtles *Chelonia mydas* occur (Ross and Barwani, 1981) and have been seen in numerous sites including in a sandy cove just north of Marsa Mubarak (Edwards *et al.*, 1981), Old Quseir (Gubbay and Rosenthal, 1982), Sharm el Bahari (Edwards *et al.*, 1981; Gubbay and Rosenthal, 1982), Marsa Umm Gheig, 43 km north of Marsa Alam and 38 km north of Marsa Alam (Gubbay and Rosenthal, 1982) and Marsa Alam Bay (Edwards *et al.*, 1981). Gubbay and Rosenthal (1982) give details of the fish fauna at each of the sites visited; in most places it is diverse and abundant.

**Scientific Importance and Research** The area was visited by the Reefwatch Egypt 1982 Expedition (Gubbay and Rosenthal, 1982), the Joint Services Expedition to the Egyptian Red Sea (Barratt, 1982) and the Red Sea Reef Study (Edwards *et al.*, 1981).

**Economic Value and Social Benefits** There are particularly good diving sites at Sharm el Bahari, Marsa Mubarak and Marsa Alam (Edwards *et al.*, 1981) and considerable tourist potential south of Marsa Alam (Wennink and Nelson-Smith, 1979). Ras Banas and Marsa Alam are important commercial fishing areas (Beltagy, 1976). Purse seine fishing catch data from 1980 give greater pelagic fish abundance at Foul Bay, Ras Banas, than in the Gulf of Suez (Shaheen *et al.*, 1982). Shells, corals and pufferfish (Triodontidae) are collected for the tourist trade (Edwards *et al.*, 1981; Gubbay and Rosenthal, 1982). The high water salinity, intense sunlight and high eutrophication of algae provide ideal conditions for the polyculture of fishes and oysters which could provide a valuable coastal industry (Clark and Vanderbilt, 1982).

**Disturbance or Deficiencies** Prevailing southerly currents carry oil down the coast from the Suez oilfields and two major spills in the Gulf of Suez in 1982 have resulted in serious damage. Fresh tar occurs along the entire coastline to varying degrees, decreasing towards the south. Tar balls are common at the strand line and tar mats occur on the shore. In 1982 particularly high concentrations of tar balls were found at Ras Banas and Marsa Alam. Bands or patches of fresh oil were particularly bad at Old Quseir, Sharm el Bahari, and Marsa Umm Gheig which had markedly deteriorated since 1981 (Frazier and Salas, 1982). Soft oil and weathered tar was found at Sharm el Bahari, the site 45 km north of Marsa Alam and the site 2 km to the south of this in the early 1980s (Barratt, 1982; Edwards *et al.*, 1981; Gubbay and Rosenthal, 1982; Hanna 1983). Oil pollution has been seen on reef flats where *Stylophora* colonies and the shells of hermit crabs were covered with tar, and in mangroves where nesting reef herons have been affected. Soft oil beneath a layer of sand is found on certain shores. Dissolved hydrocarbon measurements indicate higher concentrations from Safaga to Quseir probably due to south flowing currents and regular shipping between the two ports (Hanna, 1982 and 1983). In 1979 there was no bad pollution 75 km south of Quesir (Wennink and Nelson-Smith, 1979).

Phosphate waste is found at Hammrawein and Quseir (Barratt, 1982). The coastline from Hurghada to Port Safaga is still extensively mined (Edwards *et al.*, 1981). There are several military installations along the coast around which there is heavy littering, and at the post just south of Quseir and at Ras Banas there were thousands of tin cans (Frazier and Salas, 1982). Litter is a problem at any area with human habitation or activity including the FAO Fisheries Development Centre at Sharm Luti (Barratt, 1982), Disha el Dab'a, 2 km south of Marsa Imbarak, and Marsa Alam.

**Legal Protection** None apart from national legislation.

**Management** None.

**Recommendations** Ormond (1980a) recommended the establishment of a large Marine National Park or Biosphere Reserve, possibly within or to the south of Foul Bay where there is a large complex of inshore and offshore reefs. Further survey work is required to determine the best method of management for these reefs. Their proximity to the tourist centre of Luxor would make it an appropriate site for a park. Reefs in the area of Ras Abu Hagar may have greater coral and fish diversity than any other sites in Egypt and require particular attention. Those in Foul Bay are less well developed and it is suggested that this might be a suitable area for fisheries development. Ormond (1981) recommends the complete protection of large species of triggerfish (Balistidae), pufferfish and porcupinefish (Diodontidae) and suggests that the Department of Conservation and/or Institute of Oceanography and Fisheries should promote a local awareness programme.

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## STRAITS OF TIRAN INCLUDING TIRAN AND SINAFIR NATURAL RESERVES

**Geographical Location** Northern Red Sea, at the mouth of the Gulf of Aqaba, including Tiran Island (27°58'N, 34°35'E) and Sinafir Island (27°55'N, 34°40'E). Burqan (Barqan) Island lies to the east.

**Area, Depth, Altitude** Tiran covers an area of 19 sq. mi. (49 sq. km).

**Physical Features** The islands are scenic with well developed reefs in very clear water. Tiran is arid with a small area of salt marsh but has extensive reef adjacent to very deep water. Sinafir has extensive reef to the south-west with very clear water and depths of over 500 m. Burqan Island has fairly well developed reef in clear water with an extensive sandy area between island and reef (IUCN, 1982). Jackson, Gordon, Woodhouse and Thomas reefs are situated in the centre of the Straits and are in exceptionally clear water; vertical walls drop to a ledge at 70 m and then the drop-off continues to 1000 m. Tides create strong channels between these reefs, and only two channels are considered navigable: between Gordon Reef and the Sinai shore, and between Jackson Reef and Tiran. The area is sheltered from the prevailing north winds and is influenced primarily by southerlies and local wind conditions.

**Reef Structure and Corals** No published information.

**Noteworthy Fauna and Flora** The density and diversity of reef life is very high at Jackson, Gordon, Woodhouse and Thomas reefs (Clark and Vanderbilt, 1982). Fish are abundant including sharks (Selachimorpha) and manta rays (Mobulidae) at Sinafir Island. Green Turtles *Chelonia mydas* nest on Tiran and Sinafir Islands (Groombridge, 1982; Sella, 1981). Dugong *Dugong dugon* have been recorded at Tiran. Tiran is a haven for a variety of birds due to the lack of mammalian predators. Breeding birds include 20-40 pairs of Osprey *Pandion haliaetus*, 2-4 pairs Sooty Falcon *Falco concolor*, White-eyed Gull *Larus leucophthalmus*, Caspian Tern *Sterna caspia*, Lesser-crested Tern *S. bengalensis*, White-cheeked tern *S. repressa*, Spoonbill *Platalea leucorodia*, Reef Heron *Egretta gularis*, Little Green Heron *Butorides striatus*, Kentish

Plover *Charadrius alexandrinus* and Brown-necked Raven *Corvus ruficollis* (Bruun, 1983b).

**Scientific Importance and Research** Results of a survey carried out for IUCN are given in IUCN (1982). Considerable ornithological work was carried out by Israeli scientists when Tiran was under Israeli control.

**Economic Value and Social Benefits** The area around Tiran Island is good for fishing. The Sinafir reefs are of outstanding natural beauty and the Jackson and Gordon reefs are very popular dive sites and used by visitors at Sharm-el-Sheikh.

**Disturbance or Deficiencies** The Straits are an extremely important shipping channel and their narrowness and the presence of reefs means that there are regular shipwrecks with inevitable damage to the reefs.

**Legal Protection** Under the Prime Minister of Egypt's Decree 1068 of 1983 and Law 102, Tiran and Sinafir were declared Natural Reserves within the same boundary as Ras Muhammad, and are therefore subject to the same regulations.

**Management** Tiran first came under military control in 1967 when it was taken by the Israeli forces and was managed as a strict nature reserve during turtle and seabird breeding seasons. Since then, the continual military presence has ensured that the island has remained relatively undisturbed (Zimmerman, 1984). With its return to Egypt in 1982, the Multinational Force and Observers patrol the area and are reported to avoid the breeding areas of birds and to cause no disturbance (Bruun, 1983b). The regulations of the reserve area are not, however, enforced.

**Recommendations** There have been several recommendations for protection of the area. Part of the islands, including Sinafir and Ras Abu Fasma and the mainland sites of Sharm Mujawa (just inside the Gulf of Aqaba), Ras Fartak and Al Khurma were recommended as a reserve by IUCN (1982b). It was thought that Tiran, in a politically sensitive location, might not be suitable for incorporation in the reserve. However the International Council for Bird Preservation is anxious that Tiran should be protected (Bruun, 1983) and there seem to be good reasons for encouraging the implementation of the recently declared Egyptian reserve area. Jackson and Gordon reefs were considered a high priority for protection by Clark and Vanderbilt (1982). It has recently been recommended, under a Saudi Arabian marine conservation programme, that the Tiran Islands should be declared as a marine protectorate, to include Sharm Mujawwan and the coastal fringing reef (a core area having been designated by EPCCOM in 1984), Tiran Island, Gordon's Reef, Sha'b abu Tinun, Sinafir Island, Shusha Island and associated reefs, Al Fungur, Bir Beach, Al Khuraybah Beach, Aynunah Bay, Barqan Islands, Yuba, Walih and the Julaijila group, and the Sila Islands chain (Dakkak *et al.*, 1984b; IUCN, 1987).

# ETHIOPIA

## INTRODUCTION

### General Description

The coastline of Ethiopia lies in the southern Red Sea, extending almost to the constriction of Bab el Mandeb and the Gulf of Aden, and is just over 1000 km in length, excluding the Dahlak Archipelago. The marine environment is largely one of extensive soft substrate and shallow waters, with most areas within 50 km of the coast being less than 50 m deep (Angelucci *et al.*, 1982). Tectonic movements have caused a very variable bathymetry in some areas, notably in the Dahlak Archipelago where depressions exceeding 200 m in depth are found adjacent to several islands. Currents are poorly known and are complex among the islands. Rainfall is low, not exceeding 200 mm in a typical year, and salinities are higher than normal oceanic waters.

The geology of the Dahlak Archipelago is described by Angelucci *et al.* (1981). The sediments and rock are largely carbonate, forming a platform of limestone over Miocene salt deposits. Angelucci *et al.* (1982) regard the group as being in a regressive phase. There is very little information for the Ethiopian mainland coast, although Wainwright (1965) reports large expanses of calcareous sediments off a point opposite the Dahlak Archipelago. Mangroves are an important feature of both the mainland and island coasts.

Rudimentary, shallow fringing reefs probably occur along the mainland coast and are shown on charts (*see map*) but they have not been described. Several publications briefly describe parts of the Dahlak Archipelago (*see separate account*). In general, reefs are poorly developed structures at this latitude of the Red Sea although profuse coral assemblages flourish on some of the outer islands. There is no information on coral diversity. The most detailed, and illustrated, account of the reefs is by Civitelli and Matteucci (1981).

Small scale nesting of Green Turtles *Chelonia mydas* and Hawksbill Turtles *Eretmochelys imbricata* occurs in the Dahlak Archipelago (Groombridge, 1982). It is also important for nesting seabirds, with at least ten species present (Cooper *et al.*, 1984) including the Lesser Crested Tern *Sterna bengalensis* which nests in thousands. The Bab el Mandeb Islands support a large (6000-10 000) population of Brown Boobies *Sula leucogaster*. Cowries (Cypraeidae) from Mits'iwa (Massawa) are described by Foin and Ruebush (1969).

### Reef Resources

Ethiopia's fishery is mainly at subsistence level but there are limited commercial operations around the islands (*see separate account for* Dahlak Archipelago).

### Disturbances and Deficiencies

No information apart from Dahlak Archipelago (*see separate account*).

### Legislation and Management

Proclamation No. 137 of 1978 has, as its major purpose, the prevention of marine pollution and a seminar was held on marine pollution in 1983 under the auspices of the International Maritime Organization (IUCN/UNEP, 1985).

### Recommendations

The Dahlak Archipelago is proposed as a marine park (*see separate account*).

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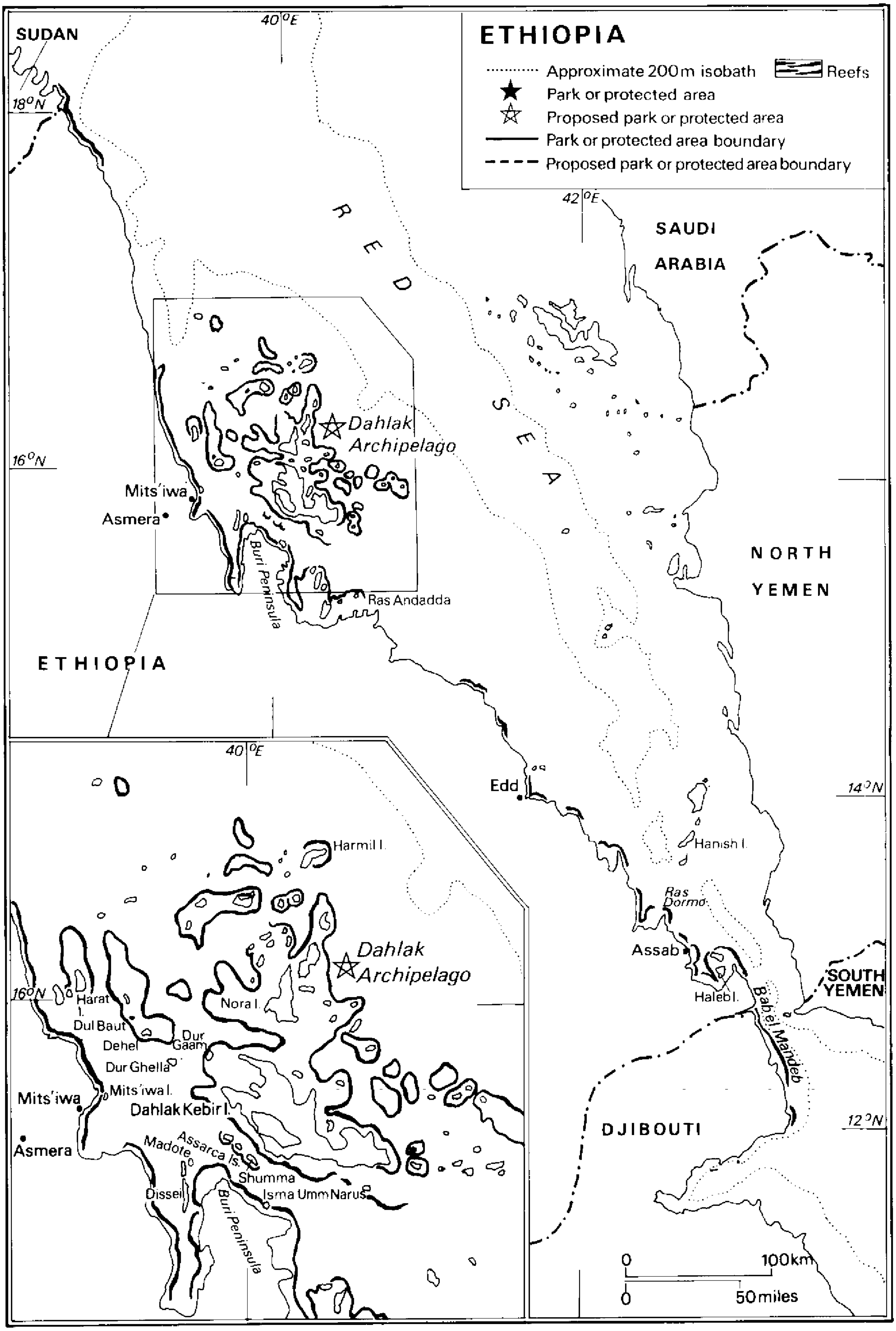
ETHIOPIA
Approximate 200m isobath
Reefs
Park or protected area
Proposed park or protected area
Park or protected area boundary
Proposed park or protected area boundary
SUDAN
40°E
42°E
18°N
16°N
14°N
12°N
RED SEA
SAUDI ARABIA
NORTH YEMEN
SOUTH YEMEN
DJIBOUTI
ETHIOPIA
Dahlak Archipelago
Mits'iwa
Asmera
Buri Peninsula
Ras Andadda
Edd
Hanish I.
Ras Dormo
Assab
Haleb I.
Bab el Mandeb
0 100km
0 50miles
Harmil I.
Harat I.
Dul Baut
Dehel
Dur Gaam
Dur Ghella
Nora I.
Mits'iwa I.
Dahlak Kebir I.
Madote
Assarca Is.
Shumma
Dissei
Isma Umm Narus

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## DAHLAK ISLANDS PROPOSED MARINE PARK

**Geographical Location** South Red Sea, off Mits'iwa (Massawa) on the north-east coast; 15°40'N, 40°10'E.

**Area, Depth, Altitude** An area of 3000 sq. km, part of which has been proposed as a National Park; max. alt. over 15 m.

**Physical Features** The archipelago numbers 130-360 islands. The inner islands have moderately or poorly developed reefs while the outer islands, which are relatively unexplored due to their inaccessibility, are likely to have better developed reefs due to their position (AWLF, 1972; Ormond, 1980). The larger islands are of limestone deposited during the Upper Pleistocene and faulted more recently to produce the present pattern of islands and troughs. Their geology has been studied by Angelucci *et al.* (1981 and 1982) and Civitelli and Matteucci (1981). The climate is arid (Berhanu, 1977) and there is little freshwater input. Tidal fluctuations of 50-120 cm have been recorded.

The inner islands are in nutrient-rich water which is fairly turbid, and consist of two groups: the southern group of Dissei, the two Assarcas, Shumma (Sciumma), Dahlak Kebir and Isma Umm Narus (Ito Umm Namus); and the northern group of Dur Ghella in the south, Dur Gaam, Dehel, Dul Baut and Harat in the north. The outer islands include Harmil outside the proposed Park boundaries (AWLF, 1972) and lie in clearer water.

In the inner islands, Dissei, (15 km x 1 km) running north-south, lies 30 km south-east of Mits'iwa, away from the other islands. It is a hilly island with rocky headlands and beaches, and a spit of sand several kilometres long runs north terminating in Madote, a coralline island surrounded by patches of reef. The two Assarca Islands (one called "black" due to the dense growth of *Euphorbia*, and the other "white" because it is barren) lie 20 km east of Dissei and 10 km west of Shumma. "Black" Assarca is surrounded by a sandy beach and has a spit to the west (AWLF, 1972). Shumma, 5 x 2 km, is the main island of the inner archipelago and is very flat with open grassland, stunted acacia scrub and mangroves in a small creek. From the north a fringing reef extends down the west coast of semi-enclosed lagoons (AWLF, 1972).

The large Dahlak Kebir Island lies immediately opposite Shumma. Isma Umm Narus (called the "mother of mosquitos", on account of a dense population of *Aedes* in the mangroves) lies 4 km from the mainland and 18 km south-west of Shumma, and is probably the richest of the inner Dahlaks in terms of both terrestial and marine flora and fauna. Dur Ghella and Dur Gaam are low, flat islands with large trees, mangroves, and fine beaches with coral heads just off shore (AWLF, 1972).

**Reef Structure and Corals** In general, coral reefs of the Dahlak Archipelago are not well developed. Wainwright (1965) states that the structures are not reefs so much as thin living veneers of corals located patchily on much older limestone and that recent reef growth is minimal. Bernhanu (1976) confirms the poor reef development. Details are available for few reefs.

The reefs at Dissei are limited but in some areas are attractive, especially the patch reefs at the south-east tip which have low coral heads with a variety of species in shallow water. Rock heads are topped by *Sargassum* under which there is live coral; below 3 m depth the *Sargassum* disappears and there are narrow reefs, 10-20 m wide which slope abruptly. There are no massive corals, but small delicate branching corals, lace coral Stylasteridae, mushroom coral Fungiidae and small staghorn coral *Acropora* sp. are found although visibility is poor. Coral diversity is higher here than elsewhere in the archipelago (Blower, 1970). Wide reef flats are found in the north, just south of Madote, in 2-4 m of water where the currents and wind are strong (AWLF, 1972). Coral heads, predominantly *Porites*, interspersed with *Sargassum*, occur on the reef flats south of the island. Heads of coral, up to 3 m high, are found west of "Black" Assarca to a depth of 11 m. Shumma's western reef has well formed coral heads with stony and soft corals, extending to about 12 m. There is high productivity on the reef and good visibility. There is no information on the windward reefs (AWLF, 1972).

*Sargassum* flats interspersed with coral heads surround Isma Umm Narus, extending on the west to 12 m (AWLF, 1972). Nora is another of the larger islands to the north and is surrounded by a reef flat, a few metres wide, and a steep drop-off to a ledge at 20 m. This then drops to depths of up to 500 m. Elsewhere there is sand with coral outcrops (Berhanu, 1976; Blower, 1970). The best patch reefs of the inner Dahlaks are found at Dehel, Dul Baut (particularly in the south-west) and Harat (AWLF, 1972).

The northern coast of Tanam has a flourishing reef with four coral assemblages (Civitelli and Matteucci, 1981): *Stylophora pistillata* and calcareous red algae in water less than 7 m deep; *A. pharonensis*, and *Lobophyllia corymbosa* beneath this; a *Porites* assemblage; and finally an assemblage of sparse corals. A brief survey of the mainland coast showed no good reefs (Wainwright, 1965).

**Noteworthy Fauna and Flora** Fish diversity and abundance in the archipelago is high. In the limited coral areas of Dissei, Pomacentridae predominate; at the south-east tip of the island many juveniles are found and large populations of *Caranx* and *Channos* are seen in shallow waters. Fish diversity increases with depth. At Madote *Dascyllus* is particularly common (AWLF, 1972). The reef at Shumma supports a diversity and abundance of fish (Blower, 1970).

Breeding populations of the Green Turtle *Chelonia mydas* and possibly the Hawksbill *Eretmochelys imbricata* occur in the archipelago (Groombridge, 1982; Hoofien and Yaron, 1964; Urban, 1970). On Isma Umm Narus there is a small beach on the east between two headlands which is used by Green Turtles; they are also reported on Shumma (AWLF, 1972). Dugong *Dugong dugon* are very scarce (Björklund, 1974) but possibly more frequent here than elsewhere in the Red Sea (AWLF, 1972).

Terrestrial fauna on some of the islands includes camels and Soemmering's Gazelle *Gazella soemmeringi* (Blower, 1970). The bird fauna includes Pink-backed and White Pelicans, Osprey, Brown Booby, Red-billed Tropicbird, Crab Plover, Sooty Falcon, Spoonbill (*Pelecanus rufescens, P. rosens, Pandion halietus, Sula leucogaster, Phaethon rubricauda, Dromas ardeola, Falco concolor, Platalea leucorodia*), heron, egret, and the Arabian Bustard *Ardeotis arabs*. Many of these nest on the islands (AWLF, 1972; Blower, 1970). Cooper *et al.* (1984) review the status of seabird colonies nesting in the Dhalak Archipelago; ten species are listed, and the area is an important site for the Lesser Crested Tern *Sterna bengalensis* which nests in thousands. Vegetation is described in IUCN (1987). Mangroves are found on several islands, with *Avicennia marina* the most common species.

**Scientific Importance and Research** Both the marine and the terrestrial features of the archipelago are of biological interest (AWLF, 1972). The high number of mangrove swamps are critical for the productivity of the region (Berhanu, 1976).

**Economic Value and Social Benefits** Six islands are inhabited though many more are used for grazing livestock. With its rich reef life and unique bird life, the archipelago provides an ideal site for the development of tourism in conjunction with a Marine Park. The coastal town of Mits'iwa, built on two islands and two peninsulas, is the only commercially developed site along the coast in this region and a tourist industry is being developed. Dogali Heroic Park at the southern tip of Mits'iwa Island (15°37'N, 39°29'E) has a library and restaurant (AWLF, 1972). The reefs around Dur Ghella and Dur Gaam are considered ideal for snorkeling (AWLF, 1972). There is a lighthouse on Shumma Island, which has no freshwater (Berhanu, 1976; Blower, 1970). Commercial fishing occurs on a small scale and could be boosted by the development of a Marine Park since it would ensure protection of fish breeding grounds. Coral and shell collecting occurred for the button industry and commercial trade since Roman times but has declined (AWLF, 1972). Local fishermen sell shells to merchants in Mits'iwa and elsewhere for the souvenir trade, and most collecting occurs at Dissei and in the Dehel/Harat group.

**Disturbance or Deficiencies** The inner islands tend to be suffering from overgrazing, particularly by goats, and erosion. They are likely to receive greatest impact in the future due to their accessibilty. Reef damage from recreational use and littering is prevalent (Berhanu, 1976). Coral and shell collecting may have been excessive in certain shallow water areas (AWLF, 1972; Berhanu, 1976; Blower, 1970). Turtles have been extensively exploited but still occur through most of the islands (AWLF, 1972). Storm damage is visible on the reefs at Dissei.

**Legal Protection** Dogali Heroic Park on Mits'iwa Island's southern coast was established in 1970/71 (AWLF, 1972).

**Management** None.

**Recommendations** In 1968, a National Park covering a major part of the Dahlak Islands, including Green Island Reserve, between Mits'iwa and the outer islands, was declared following a survey by Ray, but legislation was never passed (Ormond, 1978 and 1980). (Confirmation of the existence of Green Island Reserve has not been obtained). Originally recommended as a marine reserve by the Ethiopian Wildlife Conservation Organisation (Berhanu, 1976; Björklund, 1974; Blower, 1970), the whole Archipelago is now recommended for protection on account of its biological and touristic importance. The more varied southern group of inner islands could form a Park and the northern inner islands be incorporated into a general Reserve. Detailed surveys of the area are needed (AWLF, 1972). Green Island Reserve should be made more effective and all forms of fishing should be prohibited. It is recommended that Shumma Island and reefs 1 km from the shore, should be protected; that turtles, Dugongs, and birds be protected; that coral exploitation be prevented, and the use of explosives prohibited (Berhanu, 1977; Blower, 1970). Reefs outside the proposed Park boundary may also need management.

# INDIA

## INTRODUCTION

### General Description

The mainland coastline of India is remarkably symmetrical and unindented and is generally emergent. However, the edge of the continental shelf is strongly asymmetrical, being broad off the Ganges delta, but extending only 30-35 km off shore from the other major river deltas. It is widest off the Gulf of Khambhat (Cambay) where it reaches 400 km. Three groups of islands in the Indian Ocean, the chain of atolls comprising Lakshadweep in the southern Arabian Sea and the Andaman and Nicobar Island groups in the eastern Bay of Bengal, have fringing reefs. Lakshadweep consists of atolls arising from a volcanic basement well outside the Indian continental shelf. The Andaman and Nicobar Islands are emerged remnants of a Tertiary mountain chain, the Andaman Ridge (Ahmad, 1982a), and are located off the Asian continental shelf.

Rainfall is heaviest over most of India in June/July as a consequence of the south-west monsoon. However, the south-east (including the Tamil Nadu coast), with an annual average of 900 mm, has most rain in the last few months of the year. This is sufficient to lower the surface salinity of the sea to 25 ppt in January, despite the absence of any important river systems in the region (Couper, 1983; Pillai, 1971a; Stoddart and Fosberg, 1972). At the end of the year cyclones develop in the Bay of Bengal which affect reefs in this region, particularly those of Palk Bay. The Andamans and Nicobars are also affected by the south-west monsoon and cyclones. Lakshadweep is affected by both the south-west and north-east monsoons and has an annual rainfall of about 1500 mm accompanied by strong winds. The Gulf of Kutch, in contrast, is semi-arid.

Despite the vastness of the Indian subcontinent and the warm temperature of its coastal waters, coral reefs are present on only a few widely scattered parts of the mainland coast: the Gulf of Kutch in the north-west; off the southern mainland coast; and around a series of small islands opposite Sri Lanka. This is principally due to the presence of major river systems and the sedimentary regime on the continental shelf. Beaches of material coarser than mud and under the influence of monsoons or currents occupy 55% of the mainland coast. Offshore bars originating from the same source cause further high sedimentation and provide lagoonal conditions. Swampy deltas are common and suitable coral reef habitat is very limited. In the west, the slope is extremely gentle, and the substrate near shore is generally sand, covered with mud (Ahmad, 1982a). On the east coast clay occurs.

The principal ecological work on the coral reefs of mainland India has been carried out by Pillai (1969, 1971a, 1972, 1973 and 1977) and Mergner and Scheer (1974) who concentrated on the south-eastern section. Reddiah (1977) and Sewell (1922 and 1935) visited the Nicobars and Gardiner (1901, 1903 and 1903-6) and Pillai (1971a, b, and 1983a) studied the reefs of Lakshadweep. The 2nd Xarifa Expedition visited the Nicobars (Scheer and Pillai, 1974). Wafar (1986) provides an overview of the distribution and available knowledge on Indian reefs and further details are given in the following accounts.

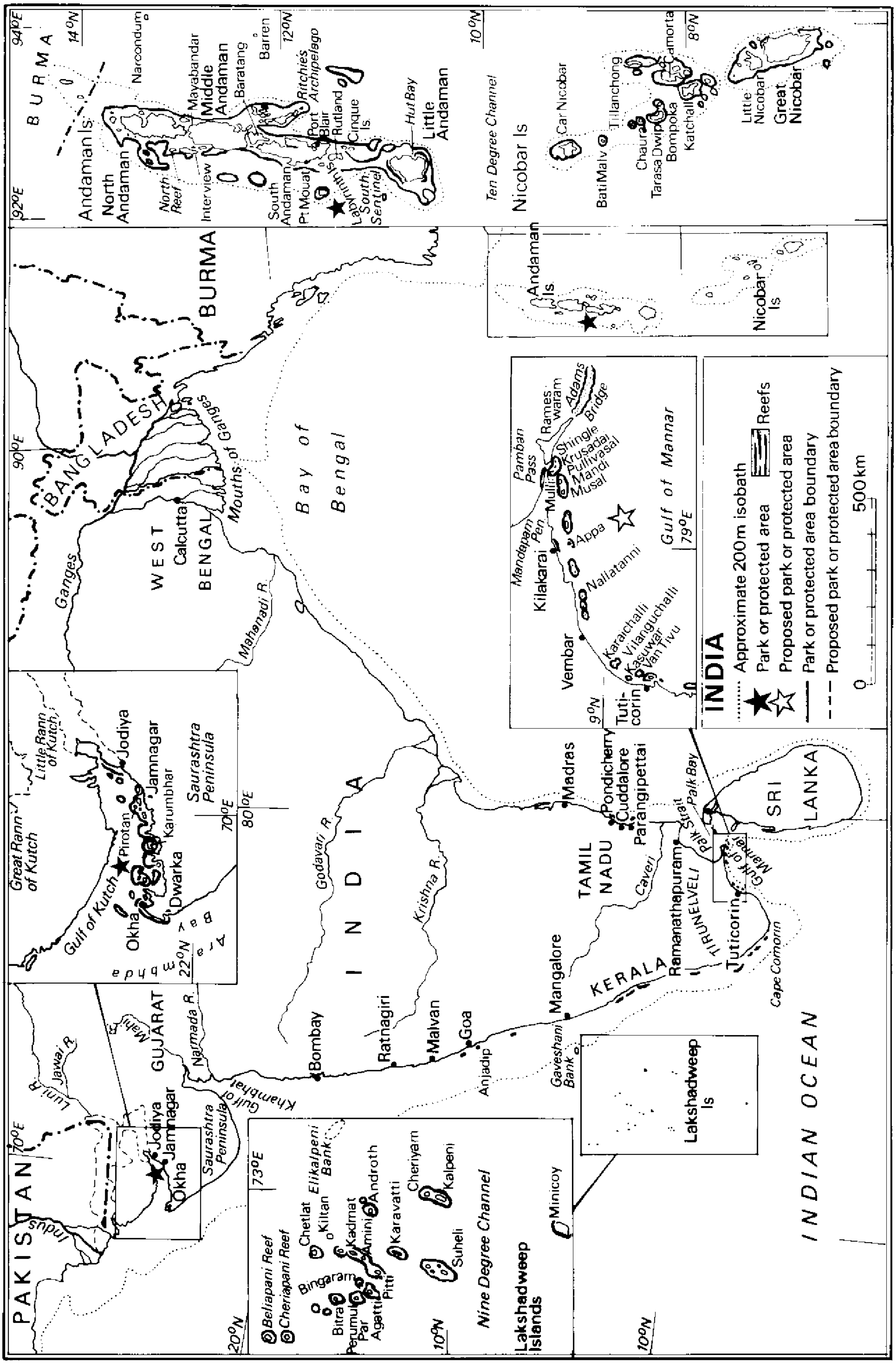
The reefs off the mainland coast and on nearshore islands are mainly fringing. The Gulf of Kutch has many islands on its southern side, around which are shallow reefs, often backed by mangroves. Qasim and Wafar (1979) recorded coral patches in the intertidal regions of Ratnagiri, Malvan and Redi, south of Bombay. Eight genera were recorded and *Porites* was dominant at all three sites, followed by *Goniastrea* and *Pseudosiderastrea*. Small-polyped ramose forms were totally absent. These coral communities are of particular interest as during the monsoon months (June-August) they survive low salinity (20-25%), very high turbidity, silting and strong wave action (Wafar, 1986). About 100 km off the west coast, off Mangalore, is the Gaveshani Bank (13°24'N, 73°45'E) at 38 m depth. Several corals have been recorded from the Bank and the genera *Porites* and *Cyphastrea* are common between the Bank and the mainland coast (Nair and Qasim, 1978).

Corals also occur on the east coast between Parangipettai (Porto Novo), south of Cuddalore (10°50'N, 79°80'E) and Pondicherry but these communities have not been surveyed (Ramaiyan and Adiyapatham, 1985). The mainland coast is still poorly known and other coral communities may yet be found. In the south-east, Palk Bay has a long fringing reef. To the south-west of the Mandapam Peninsula and Rameswaram Island, the Gulf of Mannar has about twenty small islands and numerous reefs which extend as far south as Tuticorin. The corals of these reefs are much more diverse than further north. Coral diversity in the Andaman, Nicobar and Lakshadweep groups appears lower than in south-east India, but this may be partly due to lack of work in the former areas. A total of 342 species of coral in 76 genera were recorded in India (Pillai, 1972), 32 genera from Minicoy, 34 from Palk Bay and the Gulf of Mannar, 31 from the Andamans, 9 from Lakshadweep and 42 from the Nicobars. More recent studies include Pillai (1983a and b), Scheer and Pillai (1974) and Scheer (1984).

Coral reef fish have been studied in the region of Parangipetti on the east coast of the mainland (Adiyapatham and Ramaiyan, 1985). Mangrove habitat is extensive and profuse, although many of the mangroves themselves have been destroyed; the Sundarbans and the Andamans and Nicobars are particularly important (UNEP, 1985). Sea turtle distribution is given in Bhaskar (1978 and 1979a) and Groombridge (1982). Seabird distribution on offshore islands is described in Feare (1984).

### Reef Resources

Corals of commercial value are described by Pillai (1973), and shells of commercial value, including many reef species, are described by Durve (1973). Ornamental shells, chanks and pearl oysters are the basis of an important industry in the south (Wafar, 1986). Over 2000 people rely on the shellcraft industry for their livelihood, annual exports averaging 490 tons. The industry is


INDIA
Approximate 200m isobath
Park or protected area
Proposed park or protected area
Park or protected area boundary
Proposed park or protected area boundary
Reefs
0
500km
PAKISTAN
BURMA
BANGLADESH
SRI LANKA
INDIA
GUJARAT
WEST BENGAL
TAMIL NADU
KERALA
TIRUNELVELI
Bay of Bengal
INDIAN OCEAN
Arabian Sea
Mouths of Ganges
Ganges
Indus
Luni R.
Jawai R.
Mahi R.
Narmada R.
Mahanadi R.
Godavari R.
Krishna R.
Caveri
Gulf of Khambhat
Gulf of Kutch
Great Rann of Kutch
Little Rann of Kutch
Saurashtra Peninsula
Okha
Jodiya
Jamnagar
Pirotan
Karumbhar
Dwarka
Bombay
Ratnagiri
Malvan
Goa
Anjadip
Mangalore
Gaveshani Bank
Calcutta
Madras
Pondicherry
Cuddalore
Parangipettai
Ramanathapuram
Tuticorin
Cape Comorin
Palk Bay
Palk Strait
Gulf of Mannar
Lakshadweep Is
Lakshadweep Islands
Beliapani Reef
Cheriapani Reef
Bitra
Perumul Par
Agatti
Bingaram
Pitti
Chetlat
Kiltan
Kadmat
Amini
Androth
Elikalpeni Bank
Karavatti
Cheriyam
Kalpeni
Suheli
Nine Degree Channel
Minicoy
Pamban Pass
Rameswaram
Adams Bridge
Shingle
Krusadai
Pullivasal
Mandi
Musal
Mulli
Mandapam Pen.
Kilakarai
Appa
Nallatanni
Vembar
Karaichalli
Vilanguchalli
Kasuwar
Van Tivu
Tuti-corin
Andaman Is
Nicobar Is
North Andaman
Middle Andaman
South Andaman
Little Andaman
North Reef
Interview
Mayabandar
Baratang
Barren
Narcondum
Ritchie's Archipelago
Port Blair
Rutland
Cinque Is.
Pt Mouat
Labyrinth Is
South Sentinel
Hut Bay
Ten Degree Channel
Car Nicobar
Bati Malv
Chaura
Tarasa Dwip
Bompoka
Katchall
Tillanchong
Camorta
Little Nicobar
Great Nicobar
70°E
73°E
79°E
80°E
90°E
92°E
94°E
8°N
9°N
10°N
12°N
14°N
20°N
22°N

concentrated along the east coast where there are some 40 establishments in the Ramanathapuram District of Tamil Nadu and about 20 in the Calcutta District of West Bengal, and others in the Andamans and Nicobars. *Trochus niloticus* and *Turbo marmoratus*, both mother-of-pearl bearing species, are the most important molluscs involved. Shell jewellery made from a wide range of species in Rameswaram, Keezhakkarai and Cape Comorin is sold along the shore. Sea fans and seaweeds are exported (13 tons annually) for decorative purposes (Shenoy, 1984). The collection and commercial potential of marine algae is described in UNEP (1985). James (1976) describes the bêche-de-mer resources of India. There is a spiny lobster fishery along the south-east coast of India, notably at Tuticorin, Madras and Mandapam (IUCN/UNEP, 1985), and the lobster *Panulirus polyphagus* is caught by trawling on both west and east coasts (Deshmukh, 1964). The ornamental fish trade is said to be flourishing in Calcutta, but is largely concerned with captive-bred species. Reef fisheries are generally at the subsistence level and catches are unrecorded. Wafar (1986) estimates the potential yield to be about 0.2 million tonnes a year, or about 10% of the total marine fish production in India.

**Disturbances and Deficiencies**

Some damage may have been caused to the reefs by the Crown of Thorns Starfish *Acanthaster planci*, for example in the Andamans, but the extent of this is not known.

Settlement, industry, increased fishing pressure, pollution, reclamation of wetlands and mangrove areas and deforestation are causing increasing pressure on the coastal environment (Silas *et al.*, 1985), although it has also been suggested that ecological deterioration and pollution is not yet widespread (Ahmed, 1982b). However, several recent studies (e.g. Salm, 1975a, b and 1981), have described widespread deterioration of the reefs in both sectors of the mainland and in some of the offshore islands, notably Minicoy Atoll (*see separate accounts*). Wafar (1986) describes the continued occurrence of the genera *Pseudosiderastrea* and *Porites* in Bombay waters, which are subject to heavy oil, sewage and industrial pollution. The development of Tuticorin Harbour, oil pollution and industry have caused significant damage in the Gulf of Mannar and Palk Bay area (UNEP, 1985). Pillai (1973) and Salm (1975a) describe the coral mining industry in this area in detail (*see separate accounts*) which has caused major damage to the reefs of the Gulf of Mannar, Gulf of Kutch, Andamans and Nicobars. Wafar (1986) points out that this is increasing, although in the Gulf of Kutch it has been checked. The Andaman, Nicobar and Lakshadweep islands are less threatened but there are reports of oil pollution (UNEP, 1985).

**Legislation and Management**

The Wildlife Act of 1972 protects a number of marine species including turtles, saltwater crocodiles, dugong and coconut crabs, and provides the legislation under which protected areas may be established. Chank fishing is controlled under the Chank Fisheries Act and pearl oyster fishing under the Pearl Fisheries Ordinance. In Tamil Nadu there is a minimum size limit for chanks of 55 mm diameter (Silas *et al.*, 1985). The National Committee on Oceanography is responsible for coral reef matters; its research priorities are domestic sewerage and dredging. In 1980, the Government set up a Coral Reef Committee, under the auspices of the Department of Science and Technology, to look into the ways and means of preserving India's reefs (Rashid, 1985). A Coast Guard organisation was established in 1978 to combat oil spills and carry out appropriate training. Legislation to control oil pollution has been enacted, research into new methods carried out and equipment built (UNEP, 1985). The Department of the Environment has prepared guidelines for the development of beaches and coastal zones (Silas *et al.*, 1985).

The following protected areas include or are adjacent to coral reefs:

- Gulf of Kutch Marine Sanctuary and Marine National Park (*see separate account*)
- Wandur Marine National Park (*see account for* Andaman Islands)
- Pitti Island, Lakshadweep (a bird sanctuary adjacent to coral reefs)

**Recommendations**

A national policy for the management of the coastal zone is necessary (Silas *et al.*, 1985). The following protected areas for coral reefs have been proposed.

- Gulf of Mannar Marine National Park (*see separate account*)
- An area on the Malvan coast, which would include a chain of rocky islands (15°13'N, 73°27'E) from Vengurla Rocks in the south to Sindurburg Fort in the north (N.I.O., 1980a; Silas *et al.*, 1985); reported to have abundant living corals. The Government of Maharashtra has proposed developing the area for tourism, including building a marine aquarium (Silas *et al.*, 1985).
- Andaman Islands; additional protection (*see separate account*)
- Nicobar Islands (*see separate account*)
- Lakshadweep (*see separate account*)

The creation of protected areas in the Andamans, Nicobars, Lakshadweep and the Gulf of Mannar is considered a high priority in the Corbett Action Plan for Protected Areas of the Indomalayan Realm (Thorsell, 1985).

A Marine Park has been recommended for Anjadip Island, off Binge Bay near Goa (Salm, 1975a), but it is not known if reefs occur here.

Silas *et al.* (1985) make a number of recommendations for turtle reserves, mangrove reserves and breeding reserves for commercial species such as squid, chank and mother-of-pearl. The reefs in Palk Bay, although not recommended for protected area status, need some form of management (*see separate account*).

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## ANDAMAN ISLANDS AND WANDUR (WANDOOR) MARINE NATIONAL PARK

**Geographical Location** In the Bay of Bengal, to the north of the Nicobar Islands; 10°13'-14°N, 92°-93°E.

**Physical Features** The Andaman Islands are the emerged part of a mountain chain and lie on a ridge which extends southward from the Irrawaddy Delta area of Burma, continuing the trend of the Arakan Yoma range. There are about 500 islands, islets and rocks, of which the principal are North Andaman, Middle Andaman with Ritchie's Archipelago to the east, South Andaman, Little Andaman, Baratang and Rutland Island. Barren Island lies to the east, with Narcondum, another extinct volcano, to the north (Reddiah, 1977). The larger islands are mountainous and several are fully forested. Surrounding sediments are mainly mixed calcareous with some terrigenous. A general description of the islands is given in Alagarswami (1983) and Nair (1986).

Oceanographical data are given in N.I.O. (1980b). Iso-hyets in Couper (1983) indicate that rainfall in the group exceeds 3000 mm a year, most falling during the south-west monsoon. Cyclones may develop during both monsoons and are particularly common in November. Surface temperatures range from 25° to 30°C. Salinities are usually less than 33 ppt because of the high rainfall and river influence. Conditions for coral growth are therefore probably sub-optimal, but are clearly not extreme. Currents are strong (Cipriani, 1969) with tidal ranges of 1-2 m.

**Reef Structure and Corals** Coral reefs are of the fringing type, often several hundred metres wide and separated from shore by a lagoon of similar width. Fringing reefs exist around much of the coastline and Sewell (1935) reports a barrier reef to the west. Several types of reef were described briefly by Reddiah (1977), their variety being due to the degree of exposure and the nature of the substrate. Windward reefs lie on the most exposed shores subject to the monsoonal winds, and have a more gradual seaward slope. Channel reefs are found on the shorelines between islands where wind and wave conditions are less severe; on these reefs the reef slope descends steeply and more abruptly from the edge of the reef flat. Bay reefs are found in bays and other sheltered areas and have similar exposure to channel reefs but a heavier sediment regime; *Porites* and *Favia* are the chief reef builders. Knolls occur in, or to one side of, the channels adjoining the fringing reef of the adjacent islands, and may rise from depths of 20 m. They have flat tops and are constructed from the same two genera that are dominant on the bay reefs.

The reef flats extend about 500 m from shore. Erosion channels up to 20 m wide intersect the platform, but there appear to be no surge channels or groove and spur systems. Reef edges support several genera of corals, notably *Acropora, Pocillopora, Porites* and *Favia*, and alcyonarians are common. In general, coral growth is profuse on the outer edges of the reef flats, but patchy shorewards. Banks of rubble formed by strong monsoonal winds and cyclones appear to exert a strong influence on the reef flats.

Scleractinian corals are the most important reef builders, although *Millepora* and octocorals are well-represented. Some zonation patterns have been discerned on the reef flats, but these are not particularly distinctive, except in the case of *A. humilis* which is found along the edge of the flats where surf breaks. About 42 species of corals were recorded from the Andaman group by Reddiah (1977), 68 by Pillai (1972) and 135 by Pillai (1983b). More recent data on reef ecology and distribution is given in Pillai (1983b).

**Noteworthy Fauna and Flora** The islands have important nesting beaches for Leatherback *Dermochelys coriacea*, Hawksbill *Eretmochelys imbricata* Olive Ridley *Lepidochelys olivacea* and Green *Chelonia mydas* Turtles. Dugong *Dugong dugong* occur (James, 1985b; Whitaker, 1985). Several hundred Estuarine Crocodiles *Crocodylus porosus* occur in densities inversely proportional to human populations (James, 1985b; Whitaker and Whitaker, 1978; Whitaker, 1985). Together with the Nicobars, this is the densest population in India. The Coconut Crab *Birgus latro* still occurs on South Sentinel Island (James, 1985b). The Roseate Tern *Sterna dougallii* and Black-naped Tern *S. sumatrana* nest on the islands in unknown numbers; the Sooty Tern *S. fuscata* may also breed here (Feare, 1984). There are extensive mangrove stands around many islands although many of these have been destroyed in places (Singh *et al.*, 1986; Whitaker, in press). Molluscs, particularly *Tridacna*, are also important reef builders.

**Scientific Importance and Research** A survey of the reefs of the Nicobars and Andamans was carried out by Reddiah (1977) and some information is given in Cipriani (1969). More recently a survey of the marine resources of the islands was carried out by CMFRI (Alagarswami, 1983). There is a substation of the CMFRI and an ICAR research complex at Port Blair (Salm, 1975a; Pillai *in litt.*, 25.10.85).

**Economic Value and Social Benefits** The marine resources of the islands have recently been described in Alagarswami (1983) and there is considerable potential for fisheries and tourism. In 1981 there were 1500 fishermen who landed about 1650 tons of fish (Whitaker, 1985). *Trochus niloticus* and *Turbo marmoratus* are exploited in large quantities (Silas *et al.*, 1985) and the islands are an important centre for the shellcraft industry (Shenoy, 1984). Shelling is licensed by the Revenue Department in the Andamans and there are seven zones with an annual production of about 400-500 tons of *Trochus* and 100-150 tons of *Turbo* (Nayar and Appukuttan, 1983). Other shells are also taken in large quantities for the ornamental shell trade, particularly around Port Blair (Whitaker, 1985). Commercially valuable holothurian species are abundant (James, 1976).

**Disturbance or Deficiencies** *Acanthaster planci* has recently been reported from the Andamans (Whitaker, 1985) but it is not known if it has caused any damage yet.

Massive siltation of the marine environment is resulting from widespread and uncontrolled deforestation in the hills. Large numbers of recently dead coral colonies were found at Hut Bay on Little Andaman, over which calcareous algae had started growing. The area is being intensively deforested and the water is muddy with soil run-off. To a lesser but increasing extent, effluent from the timber industry in Port Blair, Mayabandar and other towns, is also killing coral reefs adjacent to settlements which would benefit from retaining reefs in good condition for fisheries and tourism (Whitaker, in press). Sewage pollution could become a problem. Green Turtles, crocodiles and Dugongs are exploited by the islanders and are coming under increasing pressure. Explosives are used both for fishing and to blast channels, presumably causing considerable damage to reef life. Sand and coral boulders are removed from beaches for construction at Betapur, Wandur and other areas which may cause coastal erosion and affect turtle nesting (Whitaker, 1985; Nair, 1986). Intensive collection of corals and shells for the marine curio trade is reported to occur in the Labyrinth Islands off South Andaman (Nair, 1986). Oil pollution has been reported. Probably the greatest threat to the area is a proposal that the Andamans should be made a free port, with major investment and development. Tourism would be promoted at the same time, for example in the Labyrinth Islands (Mathai, 1985).

**Legal Protection** The Wandur Marine National Park has reportedly been "declared but has not been implemented" (Wafar, 1986); no information is available on its precise legal status. It covers an area of 234 sq. km of islands and reefs around the Labyrinth Islands, between the south-west coast of South Andaman and Rutland Island, and includes the islands of Tarmugli, Alexandra, Redskin, Hobday, Boat, Malay and Jolly Boys, and the islets of Pluto, Snob, Belle, Chester and Grub. It is considered to be the least disturbed group of islands with the richest coral reefs in the Andamans (Nair, 1986).

**Management** The Wildlife Wing of the Andamans and Nicobars Forest Department is responsible for National Parks (Whitaker, 1985).

**Recommendations** There have been numerous recommendations for this group of islands. A Marine Biosphere Reserve has been suggested for Ritchie's Archipelago, and a crocodile sanctuary at Port Mouat on the south-west coast of South Andaman (Whitaker, 1985). Anon. (n.d.) and Bombay Natural History Society (1983) recommend a comprehensive conservation study of the fauna and flora and the establishment of a major Oceanic Island National Park. Silas *et al.* (1985) recommend the establishment of reserves in turtle nesting areas, particularly the beaches of Kwangtung, North reef, Latouch, North Cinque, South Cinque, Interview and Twin Islands. The Andaman and Nicobar groups emerged as priority concerns at the 1985 Cochin Symposium on Endangered Marine Animals and Marine Parks. Alagarswami (1983) puts considerable emphasis on the potential for mariculture in the islands and recommends areas and species, including Giant Clam, lobster, pearl oysters, for which this would be possible. Whitaker (1985) provides general recommendations for environmental management of the Andamans. A high priority should be the implementation of the Wandur Marine National Park.

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## GULF OF KUTCH MARINE SANCTUARY AND MARINE NATIONAL PARK

**Geographical Location** North-west India, on the southern shore of the Gulf of Kutch, Gujarat State; 22°15'-23°40'N, 68°20'-70°40'E.

**Area, Depth, Altitude** Total area of the Gulf is 7500 sq. km; maximum depth 60 m, average depth about 20 m. Total area is 45 592 ha, of which 16 289 ha is incorporated within the Marine National Park. Two core areas, of 7000 ha off Okha in the west and 4000 ha off Jamnagar in the east, form much of the Marine National Park.

**Land Tenure** Park largely government-owned but details unclear.

**Physical Features** The Gulf of Kutch is an arm of the Arabian Sea, separating the Saurashtra Peninsula from the Great and Little Rann of Kutch. At its seaward (western) end it is 58 km wide, from which point it tapers gradually eastwards, extending for nearly 170 km. Most of the beaches are sandy and muddy, or have large sandstone expanses. There are between 30 and 40 islands on the Jamnagar coast in the Marine National Park, surrounded by reefs, the main islands being Pirotan of 6 sq. km (16 km north of Bedi Port) and Karumbhar (Briggs *in litt.*, 8.1.85; Chavan, 1983; Pillai *et al.*, 1980) (figures vary in references). Prior to the Pleistocene, reef development was more extensive and diverse. Since then, there has been marked tectonic uplift, the Rann of Kutch having been formed from an earlier sea. Rashid (1985) describes physical features of the Gulf. A general description of the Sind-Kutch region is given in IUCN (1983). Briggs (in press) and Chavan (1983) have described general aspects of the Park. Early brief articles on the Park include Anon. (1980) and Menon (1979).

An important feature of the Gulf is its tidal range of 4-7 m which generates fast currents of up to 2.5 m per second. These set up a remarkable "dynamic barrier" (Nair, 1984) whereby the outflow of the Indus River is deflected away from the mouth of the Gulf. As a result, much of the sediment from the Indus is carried out to sea and the Gulf has less sediment than other parts of the western Indian coastline. Nevertheless, turbidity is still very high due to cyclones, wind-blown sediment, river discharge along the southern shore of the Gulf and terrigenous input resulting from human activities, with visibility usually less than 1 m, and conditions are suboptimal (Chavan, 1985 and *in litt.*, 23.1.85). Salinity is close to the oceanic level (Briggs *in litt.*, 8.1.85). The climate is semi-arid, usually with less than 400 mm rain a year, although double this amount has sometimes fallen in recent years.

**Reef Structure and Corals** Pillai *et al.* (1980) describe the coral communities as patchy coral growths rather than as reefs, as they are found on intertidal sandstone or on wave-cut, eroded shallow banks. They are found around many of the islands and in patches between them, and are generally restricted to areas exposed to the strongest tidal currents (Brigg *in litt.*, 8.1.85), which probably permit coral growth so far from other areas of reef development. Living corals are confined to northern and western sides of the islands, where currents are strongest. They are restricted to the edges or undersides of boulders, but cover may approach 100% in pools washed continuously by tidal currents (Briggs *in litt.*, 8.1.85). The most northerly coral patches are found at Mundra Reef and Pirotan Island, where they occur about 3 km off shore (Chavan *in litt.*, 23.1.85; Gideon *et al.*, 1956), but solitary corals are found as far as Jodiya (Jodhya) in the east and Dwarka on the Saurashtra coast (Briggs *in litt.*, 8.1.85). They are difficult to approach due to vast intertidal mud flats and rapid tide changes.

The coral fauna includes 40 hermatypic and 4 ahermatypic species in 21 genera (Chavan, 1985; Patel, 1985a and in press), and 12 species of soft coral in 11 genera (Patel, 1985a). The fauna is currently being revised (Pillai *in litt.*, 25.10.85). There appears to be a total absence of ramose corals, and *Acropora, Pocillopora, Stylophora* and *Seriatopora* have not been found, although semi-fossilised *Acropora* fragments occur in the sand bars. *Millepora, Heliopora* and *Tubipora* are also absent. *Porites* occurs, but is evidently not as abundant as in the recent past (Pillai *et al.*, 1980).

**Noteworthy Fauna and Flora** The area includes the best mangrove forests of the west coast and the only mangrove forests in Gujarat; these are described in detail by Chavan (1985) and Rashid (1985). They support large breeding colonies of storks, herons, egrets, ibises, spoonbills, darters and cormorants (Rashid, 1985). Shores other than those formed from coral reefs are composed largely of sand and mud and have high invertebrate productivity (Briggs *in litt.*, 8.1.85). As a result there is a diverse avifauna and the Gulf is a wintering ground for vast numbers of waders and for Greater *Phoenicopterus ruber roseus* and Lesser *P. minor* Flamingoes. The fish fauna in this area is described by Chhayya and Patel (1978). The invertebrate fauna of the area is diverse and is described by Chavan (1983), Menon *et al.* (1961) and Gideon *et al.* (1956). The echiuran *Rubicelatus pirotansis* is described by Haldar (1985). Green Turtles *Chelonia mydas* (the most common) and Olive Ridleys *Lepidochelys olivacea* breed on Gulf beaches, and the Leatherback *Dermochelys coriacea* is occasionally sighted (Bhaskar, 1979a), but these are apparently feeding individuals only. The Dugong *Dugong dugon* is possibly extinct in the area.

**Scientific Importance and Research** The area appears to be one of the biologically richest in western India (Rashid, 1985; Salm, 1975a). The coral reefs themselves are noteworthy on account of their isolation as they are the most northerly reefs in the Indian Ocean by about 1000 km. The area forms an especially rich oasis for many taxa, in some cases with considerable biogeographical importance (Rashid, 1985). Research is conducted on shellfish and prawn farming. A number of fisheries research projects are underway at Okha (Briggs *in litt.*, 8.1.85). There is little research on the biology of other commercial species or on controlling exploitation of stocks, apart from pearl oysters. An Oxford University expedition surveyed the reefs and avifauna of the area (Briggs *in litt.*, 8.1.85; Briggs, in press).

Pirotan Island has been used by WWF-India since 1978 as a site for nature education camps for school children, subsidised by the State Wildlife Department. Some 5000 mangrove seedlings were planted by participants at the 1981-82 camp. Okha and Pirotan Islands have also been used for many years by students of marine biology (Bhatia, 1980-81; Rashid, 1985).

**Economic Value and Social Benefits** The first priority for the region is to secure its conservation (Chavan, 1983). Aspects such as tourism, which could yield revenue, are not being strongly promoted at present. However, the area receives a number of visitors and natural history tours are undertaken. The Pearl Oyster *Pinctada furcata* has long been exploited and was once one of the three best pearl fisheries in the world. It is now in decline and the only pearls produced come from the Windowpane Oyster *Placuna* sp. (Briggs *in litt.*, 8.1.85; Patel, 1985c) which is also used for lime (Durve, 1973). Chanks are fished near Port Okha (Jones, 1968). Fishing is traditionally important, but is not generally carried out close to the reefs (Briggs *in litt.*, 8.1.85).

**Disturbance or Deficiencies** The area has occasionally experienced cyclone damage; a typhoon in 1976 caused some reef damage (Briggs *in litt.*, 8.1.85). Dredging of sand for the cement industry has caused substantial destruction and the associated increase in turbidity may be the most important factor in the decline of marine life, about 50% of the coral having been destroyed (Patel, 1985b; Rashid, 1985). This is expected to continue for some years over an area of at least 1359 acres (550 ha) (Briggs *in litt.*, 8.1.85). The salt residue "bittern" is polluting the Gulf (Rashid, 1985) but new reprocessing plants will reduce this (Briggs *in litt.*, 8.1.85). Industrial waste from shore facilities is not, at present, discharged into the Gulf (Chavan *in litt.*, 23.1.85). The floating oil terminal set up by the Indian Oil Company at Vadinar is said to pose a serious pollution threat (Rashid, 1985; Anon., n.d.).

The tidal regime of the Gulf of Kutch makes it suitable for the extraction of tidal power, and the area may be chosen for the construction of a dam (Nair, 1984). The consequences of this would be extremely severe and damaging to the marine life, especially to the coral reefs whose existence appears to depend on the special combination of tides and currents.

Turtles may be hunted and their eggs taken by jackals and traded illegally (Bhaskar, 1979a) but Chavan (*in litt.*, 23.1.85) states that turtles are not hunted and eggs are not collected on the Jamnagar coast of the Gulf. Molluscs are collected but pearl oysters, once the basis of a substantial industry, are severely depleted (Patel, 1985c). Human activity on the islands has had an impact on nesting bird populations. Overzealous and uncontrolled collection of specimens by numerous students and others poses a threat to the marine life (Haldar, 1985).

The salt industry occupies a large part of the coastal strip and has caused the removal of an extensive area of mangroves (Briggs *in litt.*, 8.1.85). Salt workers increase pressure by cutting mangrove scrub for fuel and fodder, and mangroves have been virtually destroyed in some areas. Large stands still exist elsewhere, such as on Pirotan, and protection has considerably aided existing stands (Anon., n.d.; Rashid, 1985; Chavan, 1985). Pilgrims regularly visit shrines on Pirotan and Karechusna and have been responsible for some mangrove destruction.

**Legal Protection** The Marine National Park and Marine Sanctuary were established in 1982 and 1980 respectively, under the provisions of the Wildlife Protection Act, 1972. The Marine Sanctuary covered an area of 270 sq. km from Okha to Jodhya. The core area of 110 sq. km was subsequently notified as a Marine Park, comprising areas of 7000 ha off Okha in the west and 4000 ha off Jamnagar in the east (IUCN, in prep.). In 1982, the protected area was enlarged to over 400 sq. km (Rashid, 1985). According to the official park plan, the protected areas are broken up into a mosaic. The area gazetted under the Marine National Park cannot be degazetted except by central government, while the Marine Sanctuary can be degazetted by state government.

The authority of the Park is restricted to islands and mainlands on the Gulf, and to some reefs exposed only at low spring tides. Thus it extends to low water only but appears to include jurisdiction over fishing. Nevertheless, protection reportedly extends over all marine life although fishing is allowed on the reefs at high tide. Stake nets and lines may not be set on the reefs (Briggs *in litt.*, 8.1.85) and fishing with dynamite and poison is prohibited.

**Management** The Park and Sanctuary are administered by the Conservator of Forests (Anon., 1985). The Park offices are based at Jamnagar and as yet there are no other facilities, apart from two boats for visiting the area. A warden is to be appointed shortly (Briggs *in litt.*, 8.1.85). Recently it has been decided that new industries may not be established in the Marine Park belt and the salt industry may not release its waste back into the Gulf; the bittern is now to be reprocessed (Anon., 1985). The pearl oyster fishery has been temporarily halted on account of overexploitation, and coral collecting has been checked (UNEP, 1985). Fish poisoning and dynamiting within the Sanctuary has been stopped. The Government has taken back some of the leases for sea dredging in exchange for limestone leases on land. Mangrove destruction is being controlled through public education programmes and patrolling (Anon., 1985).

Experimental mangrove replanting, particularly in the vicinity of reefs, has been carried out for two years with some success (Chavan *in litt.*, 26.12.84). *Avicennia marina* has been planted on sandy, seaward areas, with *Ceriops* and *Rhizophora mucronata* in muddy, protected areas. Seedlings for these species are obtained from nurseries established for this purpose. The programme has resulted in reduced sedimentation and less deposition of sand and mud on reefs, and many new coral colonies are developing (Chavan *in litt.*, 26.12.84).

**Recommendations** Silas *et al.* (1985) emphasize the need for improved zoning and delineation of the Park and Sanctuary which are currently very confused. Rashid (1985) describes long-term plans for the Park which include the establishment of a museum, aquarium, marine laboratory, glass-bottom boats, accommodation and a variety of facilities for tourists and scientists, including an educational/ scientific centre on Pirotan and an oceanarium at Okha, at Arambhda Bay (Anon., 1985). There is also a need for increased monitoring, halting of sand dredging, establishment of a research programme and the appointment of a marine biologist. Patel (1985a) makes a number of suggestions for improved management of the corals within the park area. A provisional plan for Pirotan has been produced (N.I.O., 1978). Recommendations for the management of the pearl oyster fishery are given in Patel (1985c).

## GULF OF MANNAR PROPOSED MARINE NATIONAL PARK

**Geographical Location** South-east Indian mainland, from Tuticorin to Adams Bridge, Tamil Nadu, in the Bay of Bengal; 8°48'-9°14'N, 79°9'-79°14'E (also given as 8°50'-9°10'N, 78°10'-79°10'E (Venkatesan, n.d.).

**Area, Depth, Altitude** Area of islands 625 ha; area of proposed park over 200 sq. km, stretching 140 km along the Gulf; reefs in no more than 6 m depth.

**Land Tenure** Islands are Government-owned except Nallatanni, which is partly privately owned, and Hare which is entirely privately owned.

**Physical Features** The area includes a chain of about 20 coral islands and reefs, which extend along the northern shore of the Gulf of Mannar from Tuticorin to Rameswaram Island and are described by Stoddart and Fosberg (1972) as a discontinuous barrier reef. There are four main groups of islands, the Tuticorin group lying in Tirunelveli District and the other three in Ramanathapuram District (spellings and areas of islands quoted in the literature seem to be very variable):

The Tuticorin group includes: Van Tivu 16 ha; Karaichalli (Maraichalli) 16 ha; Kasuwar (Kasuvar, Kashwar) 19 ha; and Velanguchalli (Vilanguchalai, Vilanguchalli) 1 ha. A brief description of each island is given in Venkataramanujam *et al.*, 1981). The Vembar group includes: Upputanni (Upputhani) 30 ha; Puzhuvunnichalli (Pulvinichalli) 6 ha; and Nallatanni (Nallathanni) 110 ha. The Kilakarai group includes: Anaipar (Anaipur) 11 ha; Valliamunai (Valiamunai) 7 ha; Poorarasanpatti (Poovarasampatti, Poovarasanpatti, Kilinjan Paar) 0.25 ha; Appa 23 ha; Talairi (Talaira, Talaivi) 75 ha; Valai (Vali) 10 ha; and Mulli (Pulli) 10 ha. The Mandapam group lie about 5-10 km off shore and include: Musal (Hare, Musal Thoevu) 129 ha; Manoli (Manauli) 26 ha; Manoliputti (Manolipatti) 0.34 ha; Poomarichan (Poomarchan) 17 ha; Pullivasal 81 ha or 30 ha; Krusadai 49 ha or 66 ha (3 km x 0.5 km); and Shingle 28 ha or 13 ha.

Additional islands mentioned in the literature are Balayamunai, Shuli, Kariya, Vilangu, Koswar, Pandyan, West and New. Stoddart and Fosberg (1972), Venkatesan (n.d.), Menon (1982) and Silas *et al.* (1977) provide basic information for each island. Apart from Shingle, which is composed of coral rubble on a reef patch, all are low sand structures. Salm (1975a) gives detailed accounts of Krusadai, Shingle, Pulli and Pullivasal Islands. Krusadai lies at the eastern end of the chain; it has sandy beaches on the south and north-east; in the north-west the shore is fringed with mud and mangroves. Galaxea Reef lies off the east coast and is exposed at low tide and there is a shallow lagoon on the southern side.

The numerous reefs are mostly fringing reefs around the islands, or patch reefs rising from the shallow sea floor (Pillai, 1971a, 1972 and 1977). Some reefs encompass several islands, such as that surrounding Krusadai and Pullivasal, and that around Hare, West, Manauli and New Islands. Fringing reefs usually lie 100-150 m from the islands and are fairly narrow (Pillai, 1971a, 1972 and 1977; Rajendran and David, 1972), extending 0.5-1 km from the shore of the smaller islands, in some cases more or less continuously around the perimeter, and in others only in isolated patches (Venkataramanujam *et al.*, 1981). Patch reefs arise from depths of only 3-5 m, but may be 1-2 km in total length (e.g. Manauli Reef) with a reef flat of 100 m width. There is a fringing reef on the mainland at Kilakarai (Reddiah *et al.*, 1974).

Although the Gulf of Mannar is located immediately adjacent to Palk Bay (*see separate account*), there are some important differences in the oceanographic conditions of the two areas. The Gulf of Mannar is more open and slightly deeper in the vicinity of the reefs. Although reef slopes only extend to a very few metres depth, water 5-10 m deep lies much closer to the reefs. The Gulf also has slightly higher surface temperatures (Pillai, 1971a). Water clarity tends to be slightly greater in the vicinity of several of the reefs, but is still turbid, with visibility ranging from a maximum of 5 m to less than 1 m. It is more protected from the north-east monsoon winds than is Palk Bay, but is affected to a greater extent by the south-west monsoon although this is fairly dry here. Tidal range is under 1 m. Annual rainfall is 760-1270 mm, most falling during the north-east monsoon from October to December. The climate is typically tropical with temperatures of 25-31°C (Venkatesan, n.d.).

**Reef Structure and Corals** A general survey of the reefs is given by Rajendran and David (1972) and brief descriptions are given in Venkataramanujam *et al.* (1981) and Mahadevan and Nayar (1972). Pillai (1971a, 1973 and 1977) lists coral species found off Krusadai, Shingle, Pullivasal, Pulli, Manauli, Hare and New Islet. Despite the high sediment loads and low water clarity at all localities, 117 species were recorded. Over 15 species in the genus *Acropora* (excluding those found in Palk Bay only) and a similar number of *Montipora* species have been found. The foliaceous species *Echinopora lamellosa* has been recorded although this genus is absent from Palk Bay. *Porites solida* and *P. somaliensis* are the most important reef-builders. In general, the reefs of the Gulf of Mannar are more luxuriant in diversity and abundance than those of Palk Bay, as a result of better environmental conditions.

The most detailed account of a reef in the Gulf of Mannar is that for Manauli Reef (Mergner and Scheer, 1974) which is considered to be representative of the reefs associated with sand cays near Mandapam. The reef flat extends about 300 m from the shore, with a zone of seagrass *Thalassia* sp. near the shore followed seaward by zones of dead and living *Porites* and then zones of other faviid corals and *Montipora*. The outer edge of the reef flat dips gradually to over 1 m below low water where zones of *M. foliosa, Acropora hyacinthus, A. surculosa* and *A. formosa* occur. The seaward reef slope drops to 4-5 m, and is characterized by *Symphyllia recta*. Coral colonies were often very large, but sparse, and in general growth of the reef was very poor. The reef at Appa Island is described by Reddiah (1970).

**Noteworthy Fauna and Flora** The Gulf of Mannar is particularly important for its feeding population of Green Turtles *Chelonia mydas* and resident Dugongs *Dugong dugon*, both being dependent on the large areas of seagrass in the Gulf, particularly around Musal, Appa and Balayamunai Islands (Salm, 1975a; Silas *et al.*, 1977). The Olive Ridley *Lepidochelys olivacea* also occurs (Salm, 1975a). James (1985a) describes the echinoderms of the proposed Park area. Gravely (1927) described the littoral fauna of Krusadai, and Satyamurthi (1952 and 1956) described the molluscan fauna. Vegetation and trees are found on all islands except those in the Tuticorin group. Terrestrial vegetation of the island is briefly described in Venkatesan (n.d.) and of Krusadai in IUCN (in prep.). Mangroves are found on all the island groups, particularly in the Mandapam group (Silas *et al.*, 1977). Algal beds in the area are described by Subramanian *et al.* (1985). Encrusting foraminiferans of Krusadai Island were described by Daniel (1949).

**Scientific Importance and Research** The reefs of several of the islands are fairly easily accessible to researchers from Mandapam and so have been well-studied. They are considered the most diverse and best developed on the Indian mainland. Krusadai is considered to be of exceptional biological interest (Salm, 1975a and 1981). A marine biological station was established by the Fisheries Department on the island in 1928 and the island is visited by large numbers of students on field trips. CMFRI has regional offices at Tuticorin and Mandapam Camp and has carried out surveys of the islands and reefs to a depth of 5 m (Silas *et al.*, 1985). Nesting behaviour of turtles has been studied (Salm, 1975a) and Azariah and Pillai (1985) carried out a study on the hemichordate *Phycodera flava*.

**Economic Value and Social Benefits** Most of the islands have no freshwater and are therefore uninhabited. Nallatanni, Krusadai and Mulal have springs and are settled. The park area is a traditional fishing ground used by large numbers of fishermen from the mainland and Rameswaram Island, particularly from mid-October to mid-April (Salm, 1975a; Venkatesan, n.d.). Venkataramanujam and Santhamam (1985) describe the reef fishery, which takes parrotfish, carangids and triggerfish. Total fishery production, including pelagic fish, in the area was 2375 tonnes in 1982 and 2150 tonnes in 1983. Chank and pearl fishing are important activities, the most productive beds in India occurring in this area as well as the Windowpane Oyster *Placuna placenta* (Durve, 1973; Venkataramanujam *et al.*, 1981). Large quantities of molluscs for the ornamental shell trade are collected around Tuticorin and Rameswaram, within the proposed park area (Kannan *in litt.* 28.7.80). Holothurians, the hemichordate *Ptychodera falva* (for biological specimens) and marine algae are harvested in large quantities (Silas *et al.*, 1977 and 1985; James, 1976 and 1985a). The illegal mining of the reefs is a major economic activity and is discussed below. In 1977, there were plans to develop the area for tourism (Silas *et al.*, 1977).

**Disturbance or Deficiencies** The reefs have undergone noticeable deterioration (Pillai, 1971a and 1973). Although not proven, this may be due to increased water turbidity as a result of large scale coral mining (Mahadevan and Nayar, 1972; Pillai, 1973; Silas *et al.*, 1977). Coral mining may also be causing coastal erosion on the mainland and islands, one of the islands of the

Manoli group now being submerged at high tide (Silas *et al.*, 1977). Coral mining is centred on the reefs of the Tuticorin group where over 400 people are involved, producing 10 000 tons of lime a year (Venkataramanujam *et al.*, 1981). Extensive areas were leased for this purpose by the government until 1979 when the leases ceased; however mining continues illegally. *Acropora formosa* fragments, known as "challi", are collected for lime preparation; in Tuticorin about 30 boats are involved in this activity and collect over 80 000 cu. m. a year. The genera *Porites* and *Favia*, the principal reef builders and the most abundant massive species on the reef, are quarried for use as building blocks, the construction of roads and for the lime industry. This involves about 10 boats; the reef is broken with bars and loaded into boats at low tides, resulting in the collection of 30 000 cu. m or 15 000 tons a year. Similar volumes are collected elsewhere in the Gulf of Mannar (Salm, 1975a and b). It is estimated that the amount of coral removed over seven years from Mulli, Talaivi and Vali in the Kilakarai group is equivalent to a strip of reef 1 m deep x 18.5 m wide x 10 km long.

Dugong and turtles are extensively hunted (Anon., n.d.) The Dugong used to be abundant but is now very rare (Salm, 1975a). It is estimated that the annual catch of turtles from the Gulf of Mannar is 3000-4000 (Salm, 1981), of which 75% is the Green Turtle.

There used to be considerable disturbance to the marine environment of Krusadai by students on collecting trips but a ban on collection of specimens, except in the case of approved scientific studies, has now been imposed (Salm, 1975a). Fishing using drift nets, traps and long lines, and bottom set gill nets for lobster has also caused damage (Silas *et al.*, 1977). A current threat to the proposed Park is the proposed Sethusamudram Channel Project which will cross from Palk Bay to the Gulf of Mannar. The development of Tuticorin Harbour and associated industrial activities and oil pollution has also had a negative impact on the reefs (UNEP, 1985). In 1964 a cyclone damaged Rameswaran and Pamban (Salm, 1975a). Silas *et al.* (1985) give further details of damaging activities within the proposed park area.

**Legal Protection** The government of Tamil Nadu has recently banned the quarrying of massive corals (Venkataramanujam *et al.* 1981) although Whitaker (*in litt.*, 12.10.84) reports that dead coral on the landward side of the islands may be extracted under lease agreement. Collection of marine organisms, unless for approved scientific purposes has been prohibited around Krusadai (Salm, 1975a).

**Management** There has been an improvement in enforcement of the national legislation prohibiting the hunting of Dugong, and local fishermen are now aware of the ban (Silas *et al.*, 1977). There has been very little enforcement of the coral mining legislation.

**Recommendations** In 1976, a committee of the Government of Tamil Nadu proposed that the area from Rameswaran to Tuticorin should be declared a Marine National Park, with the coral islands to the west and south of Krusadai Island declared as coral reserves and protected accordingly. This intention was published in 1980 under Section 35 of the Wildlife (Protection) Act of 1972, and the area now needs to be notified as a sanctuary under Section 18 of this Act. The Government has constituted a Committee which will define the boundaries and prepare a development plan (Silas *et al.*, 1985; Venkatesan, n.d.). The Forestry Department has made proposals for staffing of the park area.

Silas *et al.* (1985) provide detailed recommendations for the establishment of a series of zones. Some islands could be reserved for tourism, others for scientific study. Facilities for education, including an oceanarium, are required. It has also been suggested that the development of tourism should be confined to the mainland coast and not allowed to extend to the islands, apart from setting aside areas for snorkelling and diving. The needs of the fishermen must be taken into account. The marine parks centre could be based on Krusadai (IUCN, in prep.). Silas *et al.* (1977) recommend priority actions which include total prohibition of coral mining on the islands; the establishment of the park area in the Vembar, Kilakarai and Mandapam groups of islands; prohibition of collection of biological specimens and live shells; total protection of dugong, turtle and dolphins; control of seaweed collection and fishing activities; reduction in livestock on islands; and prohibition of fuel wood collection on the islands.

Effective protection and management of the important Dugong and Green Turtle populations emerged as two of the priority concerns at the 1985 Symposium on Endangered Marine Animals and Marine Parks held in Cochin. Earlier recommendations included the creation of a Dugong Sanctuary in the area from Valinokam to Pamban (Silas *et al.*, 1977). Venkataramanujam and Santhanam (1985) make recommendations for management of fishery resources but these have not been published. Recommendations for the management of the commercially valuable holothurians *Holothuria scabra* and *H. spinifera* are given in James (1985a).

Silas *et al.* (1985) recommend that the feasibility of a breeding reserve for chanks should be investigated, and suggest an area of 100 sq. km between 16 and 30 m depth off Tuticorin.

## LAKSHADWEEP (LACCADIVES)

**Geographical Location** Arabian Sea, 200-200 km off the coast of Kerala, south-west India; 8-12°N, 71°45'-73°45'E.

**Land Tenure** Partly privately owned. The islands are administered from Kavaratti and are divided into three groups (Amindivi, Lakshadweep and Minicoy) for this purpose.

**Physical Features** Lakshadweep forms the northern part of the Laccadive - Chagos Ridge and is the largest group of atolls in the Indian Ocean. There are 11 major islands and lagoons (atolls) (Kavaratti, Kalpeni, Agatti, Chetlat, Bitra, Kiltan, Kadmat Island, Amini, Bingaram, Suheli, Minicoy), 4 major submerged reefs (Beliapani, Cheriapani, Perumul Par, Androth) and 5 major submerged banks (Bassas de Pedro, Sesostris, Coradivh, Amini-Pitti, Elikalpeni) (Bryan, 1953, updated by Siddiquie and Mallik, 1973). The southernmost atoll, Minicoy (8°18'N, 73°E), is separated from the others by the Nine Degree Channel. Siddiquie and Mallik (1973) give details of the areas of the islands and lagoons.

The islands are generally narrow and arcuate and are situated on the eastern rims, with the lagoons on the west, enclosed by elliptically-shaped reefs: Kiltan, Chetlat and Minicoy are good examples. The beaches on the lagoon side of the islands are sandy. On the eastern sides they are storm beaches, formed of coarser sediments, often with boulders, created during cyclones from the east (Siddiquie, 1980). The atolls may be protected to some degree by India in the north-east monsoons. A few of the smaller islands are sand cays only.

Lagoon depths average 3-5 m, although 10 m may be reached, for example in parts of the lagoons of Bitra and Minicoy. The lagoon slopes bordering the islands are usually smooth. The central part of the lagoons are rugged due to outcrops of coral at the edge of the reefs. The sedimentology of several lagoons, particularly Kavaratti and Kalpeni, has been described (Mallik, 1976 and 1979; Siddiquie and Mallik, 1973 and 1975; Venkatesh, 1974). The seaward profiles of the atolls are typical of all oceanic atolls, dropping steeply to a depth of several hundred metres (Gardiner, 1903). The seaward reef has a steeper slope and a well-defined wave-cut platform extending from the reef margin 50-100 m seawards. Depths of more than 60 m are reached within a short distance (Siddiquie and Mallik, 1975). There are a number of terraces at different depths (Siddiquie, 1975). The larger islands have steep slopes on their eastern faces, with no definite reef flat, down to a drop-off at 60-100 m. The seaward sides of western rims descend more gradually.

Minicoy Atoll is oval-shaped and about 10 x 6 km with the main island, also called Minicoy, on the emergent eastern rim. The island is about 9.5 x 0.65 km, with an area of 4.4 sq. km and a maximum altitude of 1.8 m. The lagoon is about 35 sq. km with a maximum depth of 13 m (Pillai, 1983a). Kavaratti Island is narrow and arcuate with a lagoon about 4.5 km long and 800 m wide. Kalpeni Island (1.3 x 5 km) and Cheriyam Island (2.8 km x 300 m) share a lagoon (10.5 x 4.3 km) and are connected to each other at low tide. The maximum depths of Kavaratti and Kalpeni lagoons are 3 and 5 m, respectively. The geology, topography and sedimentology of these atolls are described by Mallik (1979 and 1985b) and Siddiquie and Mallik (1975).

The climate is typically tropical. On Minicoy, both the south-west and north-east monsoons contribute to a total annual rainfall of about 1600 mm (Pillai, 1983a); on Kavaratti and Kalpeni annual rainfall is 380-510 mm (Mallik, 1985b). The atolls are situated in the cyclonic belt and are occasionally affected by very severe winds and seas. Average temperatures are about 30°C, with only a small daily fluctuation. Currents affecting the islands are those of the monsoons and a south-easterly flow alternates with a north-westerly flow. Water temperatures range from 25° to 30°C (Mallik, 1979; Couper, 1983; Pillai, 1983a). Tides are mixed, mainly semidiurnal, with a range of 1-2 m. Oceanographic details are given in N.I.O. (1979).

**Reef Structure and Corals** All the atolls are surrounded by prolific reefs (Salm, 1975a) but there have been few detailed ecological studies. On Minicoy, three channels in the north and west break the continuity of the reef flat and it is submerged apart from the south-west, which is exposed at low tide. The commonest corals, when described by Gardiner (1903) were *Acropora* spp., *Porites* spp., *Diploastrea heliopora, Goniastrea retiformis* and *Lobophyllia corymbosa*. The southern half of the lagoon is occupied by a sand flat. Elsewhere knolls rise to near the surface, especially in the northern part, with abundant large *Porites* colonies, *Acropora* spp., faviids and abundant *Diploastrea*. One notable feature is a high cover of *Heliopora coerulea* on part of the reef in the south-west. A total of 69 species of hermatypic coral in 26 genera have been recorded from Minicoy, all of which are common Indo-Pacific or Indian Ocean corals (Pillai, 1972). On Kalpeni atoll, the reef flat at low tide around Kalpeni and Cheriyam islands has been described by Mallik (1979). It is dominated by branching *Acropora* spp., followed by *Porites* spp. and *Pocillopora* spp.

**Noteworthy Fauna and Flora** Leatherback *Dermochelys coriacea*, Olive Ridley *Lepidochelys olivacea*, Hawksbill *Eretmochelys imbricata* and especially Green Turtle *Chelonia mydas* are found. At least five uninhabited islands (Suheli Valiyakara, Suheli Cheriyakara, Bingaram, Parali and Tinnakara) and two inhabited islands (Androth and Kadmat) have nesting populations (Bhaskar, 1978 and 1979b). Molluscs include Giant Clams *Tridacna* spp. and tritons *Charonia* sp. Mallik (1979) describes molluscs from Kavaratti and Kalpeni atolls and Bhaskar (1978) briefly described cowries (Cypraeidae). The fish fauna is described by Jones and Kumaran (1980). There are dense nesting populations of Noddy Terns *Anous stolidus* and Large Crested Terns *Sterna bergii* on Pitti Island; Sooty Terns *S. fuscata* and Bridled Terns *S. anaethetus* nest on Baliapanni Island (Salm, 1975a). Audubon's Shearwater *Puffinus lherminieri*, Masked Booby *Sula dactylatra*, Red-footed Booby *S. sula rubripes* and Brown Booby *S. leucogaster* may nest on some of the islands (Feare, 1984). The terrestrial fauna of Minicoy is described by Pillai (1983a), and seagrass beds on Minicoy by Ansari (1984).

**Scientific Importance and Research** Most information on Lakshadweep concerns the most southerly atoll, Minicoy (Gardiner, 1901, 1903 and 1903-6; Pillai, 1971a, 1971b and 1983a), where there is a sub-station of the CMFRI (Salm, 1975a), and the atolls of Kalpeni and Kavaratti (Mallik, 1976, 1979, 1985a and b; Wafar *et al.*, 1985). Mallik (1979) summarizes some of the early studies, many of which were concerned with investigating the potential commercial value of the coralline deposits. The Indian Bureau of Mines investigated limestone and guano deposits (Mukherjee and Druva Rao, 1970). The Geological Survey of India carried out detailed sampling in lagoons and shallow offshore waters to assess the potential of calcareous sands for industrial use (Siddiquie and Mallik, 1973 and 1975). A Science and Technology Cell has recently been set up on Kavaratti to monitor scientific work in the islands (Mallik *in litt.*, 6.11.85). Salm (1975a) considers Lakshadweep to have the most luxuriant reef growth in India. Productivity of the reefs and seagrass beds has been studied at Kavaratti (Qasim and Sankaranarayanan, 1970; Qasim and Bhattattriri, 1971; Qasim *et al.*, 1972).

**Economic Value and Social Benefits** There are ten inhabited islands, Kavaratti being the capital. The main occupations of the islanders are fishing and coconut cultivation. Turtles and shells are also collected for commercial purposes (Bhaskar, 1978), although not on Minicoy where there is a traditional custom against killing the former. *Trochus niloticus* and *Turbo marmoratus* are collected for the shellcraft industry (Shenoy, 1984). There are abundant populations of commercially valuable holothurians but these have not been exploited (James, 1976). On Minicoy, there is an important bait fishery in the lagoon (Pillai, 1983a).

Surveys of the lagoons and shallow offshore areas by the Geological Survey of India (1967-68 and 1970-71) revealed as much as 288 million tonnes, up to a depth of 1 m in the lagoons (Siddiquie and Mallik 1973 and 1975), and 2000 million in total (Wafar, *in litt.*, 15.10.85), of very pure calcareous sand suitable for the manufacture of cement, calcium carbide and other similar products. Attempts are being made to estimate how much can be removed without damaging the adjacent islets through erosion (Mallik, 1985) and it has been suggested that 700 million tonnes could be safely extracted (Wafar *in litt.*, 15.10.85).

The islands are currently being developed (Salm, 1975a). Cottages for "domestic" tourists were being built on Kadmat Island in 1979 and tourists were visiting Bingaram to SCUBA dive (Bhaskar, 1979b).

**Disturbance or Deficiencies** Over the past decade, Minicoy has suffered severe disturbance. On land, clearance by cutting and fire has caused marked changes to the natural vegetation since about 1978 (Pillai, 1981 and 1983a). Cattle and goats have recently increased in numbers.

On Minicoy, early surveys showed luxuriant growth of living corals with no significant coral mortality (Pillai, 1971b). *Acanthaster planci* was reported to have caused some coral mortality up to 1979 but this was not serious (Murty *et al.*, 1979; Pillai, 1983a). Bhaskar (1979b) reported that *A. planci* did not occur in plague numbers and it is currently not seen (Pillai *in litt.*, 25.10.85). *A. planci* has also been recorded at Kavaratti (Sivadas, 1977). Cyclones may cause some reef damage.

Since 1980 there has been massive deterioration and mortality of both ramose and massive corals, particularly in the lagoon, largely due to human activity. On the reef flats, excavation of rock and dead coral rubble for building has been extensive. Traditionally corals are used as mortar, for building and for whitewashing houses. It is not known to what extent this has caused damage.

The main entrance to Minicoy was dredged between 1968 and 1977 by the Harbour Department, with the dredged spoil being placed into the lagoon near the north of the island, from where much of it was later washed onto the shore. In some areas, as a result of dredging and blasting, 0.5 m of sediment has buried corals, while in others corals remain visible but have been killed. It has been estimated that 75% of all the coral in the lagoon was killed in the late 1970s or early 1980s; dead corals are disintegrating and overgrown with algae, and recolonization by new corals appears to be negligible. However a study of the impact of dredging in a ship channel in the lagoon on Kavaratti showed little damage to adjacent reefs and beaches (Mallik, 1981 and 1985a). There has been significant erosion of the lagoon shore as a result of the dredging (Pillai, 1983a).

The fish and invertebrate life has also disappeared. Fish caught directly for consumption or for bait for the tuna fishery have become scarce, particularly those which require live ramose corals to hide in, and there are now not enough bait fish to supply the islanders (Pillai, 1983a). Bait fish such as *Chromis* spp. have also been directly over-exploited. All turtle species are highly sought after and turtle eggs are collected; the exception is Minicoy where turtles are hunted only sporadically (Bhaskar, 1978).

No data are available for the northern atolls of Lakshadweep but Pillai (1983a) states that on several of these the reefs have been damaged. An oil spill from an American tanker in 1974 resulted in severe mortality of intertidal reef flat organisms on Kiltan (Pillai *in litt.* to Salvat, 1978). Oil pollution has been reported from Minicoy and Kavaratti (UNEP, 1985). In 1983, there were plans for the establishment of a cement plant on Kavaratti. There is a potential threat from sewage pollution (Anon., 1986).

**Legal Protection** Corals may not be collected, except for scientific study, under an order issued by the Administrator of the Union Territory of Lakshadweep. Pitti Island has been designated as a sanctuary for birds (Bhaskar, 1979b). Turtles are protected but the legislation is not enforced.

**Management** Sea erosion is being checked by the import of granite and concrete, but this may not provide total protection. Dredging has recently been stopped (Pillai, 1983a).

**Recommendations** Several recommendations for the management of Minicoy Atoll have been made by Pillai (1983a). Deforestation should be halted, and grazing pressure on the land alleviated. A quota system for bait fish must be introduced and areas of the reef should be set aside which are not fished, so that reef fish populations can recuperate. An immediate assessment of the reef and island biota of the various atolls has been recommended in view of plans to introduce tourism (Anon., n.d.). Bhaskar (1979b) and Silas *et al.* (1985) recommend the establishment of turtle reserves on some of the uninhabited islands before these are permanently colonized, as is likely to happen due to the rapidly increasing population. The important nesting beaches of Suheli Veliyakaran, Bingaram, Thinnakara, Parali and Minicoy should be declared reserves.

Excavation of the reef flats for building materials, dredging and blasting should be controlled throughout the islands. Mallik (1985b) suggests that limited amounts of lagoonal sand can be removed from atolls such as Kavaratti, provided the reef is not damaged and that monitoring is continued throughout. It is recommended that sand should no longer be dumped at sea by the Harbour Engineering Department but should be used for industrial purposes or for reclamation. Guidelines are required for exploitation of sand on atolls other than Kavaratti. Research on the problems of sedimentation in Minicoy lagoon is required. A public awareness campaign is required. A Coastal Zone Management Plan for this group of islands is a high priority (Silas *et al.*, 1985).

## NICOBAR ISLANDS

**Geographical Location** Eastern side of the Bay of Bengal, about 300 km south of the Andaman Islands; 6°30'-9°30'N, 93-94°E.

**Physical Features** The Nicobars are high islands forming part of an emergent mountain chain, continuing that underlying the Andamans. Car Nicobar is the northernmost island and Great Nicobar is the southernmost. Between these lie Tillanchong, Katchall (Katchal), Camorta, Tarasa Dwip (Teressa), Bompoka, Batti Malv and Chaura. Fringing reefs exist around many of these, often reaching several hundred metres in width, and sometimes separated from shore by an equal distance. The islands are described by Alagarswami (1983), Eibl-Eibesfeldt (1966), Hass (1965) and Nair (1986).

The Nicobars are subject to the south-west monsoon and have an annual rainfall of 3000 mm or more a year (Couper, 1983). Apart from the monsoon storms, the Nicobars are affected by cyclones, although, being fairly close to the Equator, they lie more in the cyclone generation area than in the path of fully developed cyclones. Tides are semi-diurnal with a range of about 3 m and currents may be strong. Salinity is 33 ppt.

**Reef Structure and Corals** Sewell (1922) briefly described the reefs. More recently the 2nd Xarifa Expedition (Scheer, 1971; Scheer and Pillai, 1974) visited Great Nicobar and Tillanchong, and Reddiah (1977) visited several, unspecified parts of the group.

Reddiah (1977) divided the fringing reefs into several categories, similar to those of the Andamans. Windward reefs grow in the direction of the prevailing winds on the most exposed shores and have gradual reef slopes. Channel reefs line the sheltered shores between islands and are also found on leeward shores; they have steeply descending reef slopes. Bay reefs form in wind and wave conditions similar to channel reefs, but are characterized by much heavier sediment loads. Knoll reefs are found in the channels, often adjoining the main fringing reefs, and rise from the sea floor at about 20 m; like bay reefs, they are constructed principally of the genera *Porites* and *Favia* and alcyonarians are common. Patch reefs resemble knoll reefs but are not compact, and are covered with a fragile matrix of both dead and live corals. They develop on the inner sides of the main fringing reefs and may reach a height of 0.3 m above the surrounding reef flats.

The reef flats or platforms extend up to 1 km from the islands and develop prominent shoreward and seaward inclinations due partly to dissolution of the substrate. Five generalized types of reef flat have been defined: (1) high level conglomerate flats with prograding shores; (2) unconsolidated conglomerate flats; (3) consolidated flat conglomerates; (4) unconsolidated irregularly shaped flats, and (5) exposures of old beach rock, base rock or upraised reef (Reddiah, 1977). The seaward edges of the reef flats have a spur and groove formation in which the surge channels are about 1 m wide and deep, and are made slippery by calcareous red algae. *Porites, Favia, Acropora, Pocillopora, Montipora, Heliopora,* and *Tubipora* are common corals here, with alcyonarians and gorgonians. As in the Andaman Islands, rubble banks, attributed to monsoon winds and cyclones, are found on some reef flats.

Around Great Nicobar, corals are not especially abundant in the northern areas, although *Acropora* and *Pocillopora* are locally common (Scheer, 1971). The anemones *Radianthus* and *Discosoma* are particularly numerous and reach diameters of about 0.3 and 1 m respectively. At Tillanchong, the reef flat is 200-300 m wide, separated from a sandy beach by patches of seagrass. The dominant coral in shallow water was a lobate form of *A. palifera*, together with several *Porites* reaching 6-8 m in diameter. A greater diversity was observed below the most turbulent area and soft substrate corals were relatively abundant below the reef slope at 26 m depth, including *Cycloseris, Trachyphyllia, Heterocyathus, Heteropsammia* and *Goniopora* which reproduces by means of polyp balls (Scheer, 1960).

Altogether, about 103 hermatypic species from 39 genera have been recorded from the Nicobars (Reddiah, 1977; Scheer and Pillai, 1974).

**Noteworthy Fauna and Flora** The Nicobars (and the Andamans to a lesser degree) have more nesting Leatherback Turtle *Dermochelys coriacea* than any other site in the northern Indian Ocean and Great Nicobar is the main nesting site. Green Turtle *Chelonia mydas*, Hawksbill *Eretmochelys imbricata* and Olive Ridley *Lepidochelys olivacea* also nest in the islands. The Saltwater Crocodile *Crocodylus porosus* and the Dugong *Dugong dugon* occur (James, 1985b). Daniel and Rajagopal (1969) describe molluscs of economic value around Great Nicobar. *Trochus niloticus* and *Turbo marmoratus* are abundant. The Brown Noddy *Anous stolidus* and Black-naped Tern *Sterna sumatrana* may nest on the Nicobars (Feare, 1984). Mangroves are quite common in sheltered areas but are absent from Car Nicobar.

**Scientific Importance and Research** In 1966, a team from the Zoological Survey of India surveyed the littoral, sub-littoral and offshore zones of Great Nicobar to assess potential molluscan resources for exploitation (Daniel and Rajagopal, 1969). More recently the marine resources of the islands were described in Alagarswami (1983).

**Economic Value and Social Benefits** *Trochus niloticus* and *Turbo* sp. are collected intensively (Silas *et al.*, 1985). The islands are an important centre for the shellcraft industry (Shenoy, 1984).

**Disturbance or Deficiencies** The reefs are considered to be in better condition than many others in India but oil pollution has been recorded at Great Nicobar. *Acanthaster planci* may have caused some damage (UNEP, 1985). *Trochus* and *Turbo* are being overexploited.

**Legal Protection** None.

**Management** None.

**Recommendations** Silas *et al.* (1985) recommend that waters around the Little Nicobars, Katchall and Camorta Islands be declared as prohibited zones for mother-of-pearl fishing, up to 500 m from shore. Licences for commercial operations should be reviewed.

Turtle reserves should be established on Car Nicobar, Camorta and Great Nicobar, as these islands are developing rapidly. The Nicobars, with the Andamans, emerged as priority concerns at the 1985 Cochin Symposium on Endangered Marine Animals and National Parks.

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## PALK BAY

**Geographical Location** South-east India; to the north of the Gulf of Mannar but separated from it by Mandapam Peninsula and Rameswaram Island; the reef is centred on 9°17'N, 79°15'E.

**Area, Depth, Altitude** The reef is 25-30 km long, and generally less than 200 m wide; maximum depth about 3 m.

**Physical Features** The area is affected by both south-west and north-east monsoons (Couper, 1983). Annual rainfall varies from 762 to 1270 mm, most falling during the north-east monsoon in October to mid-December when there are occasional gales. Although no rivers or streams flow into the area, rainfall is sufficient to lower salinity from the usual 33-36 ppt to as little as 25 ppt in January. Surface temperatures vary from 24.6° to 29.1°C, with the minimum and maximum in January and April respectively. Tidal range is usually less than 1 m and the bay is calm for most of the year except at the onset of the north-east monsoon, when turbulent conditions prevail. Underwater visibility is rarely over 3 m due to the large sediment deposits in shallow water. This has a major influence on coral and other reef fauna (Pillai, 1969 and 1971a). Salm (1975a) briefly describes the physical features of the area. Sedimentology of the area is described by Mallik and Ray (1975) and Mallik (1983).

The reef runs in an east-west direction along the north coasts of the Mandapam Peninsula (which projects roughly perpendicularly from the shore of the Indian mainland) and Rameswaram Island (Pillai, 1971a). It lies about 200-600 m off shore and is broken by Pamban Pass (Channel), separating Kathuvallimuni Reef on the east and Vellapertumuni Reef on the west.

**Reef Structure and Corals** Both sections of reef are no more than gentle undulations, the shoreward "edge" of which is about 100 m broad and the crest 30 m wide. The seaward slope descends to about 3 m (rarely 4 m) over a distance of 90 m before the substrate grades into fine sand and mud. Reef structure and composition owes much to the sedimented regime of the area and vertical zonation of corals is indistinct (Pillai, 1969). Overall, however, the shoreward side of the reef has mostly encrusting and massive corals, with comparatively large polyps, and faviids are dominant. The seaward side supports small polyped, ramose forms, especially *Acropora*, *Pocillopora* and arborescent *Montipora* species, along with large polyped, encrusting and massive species.

The reef is probably not actively growing, as corals are in general poorly represented and widely spaced (Pillai, 1969). The reef flat is dominated by fleshy algae rather than by calcareous organisms. This, as well as the distribution of coral polyp size and high coral mortality, is attributed almost entirely to the heavy sedimentation particularly during the north-east monsoon. Several genera which occur elsewhere in south-east India are apparently absent from this reef but collections have not been made to any great depth (Wafar, 1986). However, over 65 species have been recorded, including a large number in the genera *Acropora* and *Montipora*. *Porites* is the most important genus in terms of abundance and reef building (Pillai, 1967a, b and c).

**Noteworthy Fauna and Flora** Turtles and Dugong *Dugong dugon* both occur in the area (Salm, 1975a). Squid breed in large numbers around Rameswaram Island (Silas *et al.*, 1985).

**Scientific Importance and Research** The reef of Palk Bay is comparatively well-known (Wafar, 1986) but its intrinsic importance is probably not as great as reefs in the adjacent Gulf of Mannar. Reef primary productivty has been studied by Balasubramanian and Wafar (1974).

**Economic Value and Social Benefits** Some of the most productive chank beds *Xancus pyrum* are in Palk Bay near Devipatnam and Rameswaram (Durve, 1973). Fishing is important in the area (Salm, 1975a). *Chanos* fry are caught in large numbers following spawning (Silas *et al.*, 1985). The collection of holothurians is an important activity (James, 1976).

**Disturbance or Deficiencies** Much of the reef is dead (Salm, 1975a). Pillai (1969 and 1973) reports that every monsoon period brings with it further coral death from sedimentation. Following the monsoon large numbers of reef corals appear freshly killed, especially on the inner side of the reef. Considerable reef deterioration is due to the collection of corals for the lime industry. At Mandapam, 50 boats are engaged in quarrying the reef and remove up to 250 cu. m of the reef daily. The most exploited corals are the massive genera which are used for the preparation of calcium carbide, cement and lime. Pillai (1973) believes that in this area coral mortality is exceeding growth.

There is widespread collection of shells, particularly *Trochus, Turbo* and other small gastropods, for the indigenous handicraft trade and for small scale export. Fishing by dynamite and for the aquarium trade seems not to occur (Pillai, *in litt.* to Salvat, 1978). It has been estimated that the total turtle catch for Palk Bay is about 1000 individuals, 75% of which are the Green Turtle *Chelonia mydas* (Salm, 1981). Dugong are also taken occasionally.

**Legal Protection** None.

**Management** None.

**Recommendations** Mallik and Ray (1975) suggest that corals could be mined for industrial purposes without causing damage to the reefs, but this clearly needs further research. The *Chanos* fishery should be regulated and there should be some protection of the squid breeding area around Rameswaram Island. A breeding reserve for chank should be considered, perhaps an area between 8 and 10 m depth off Tondi (Silas *et al.*, 1985).

# INDONESIA

## INTRODUCTION

### General Description

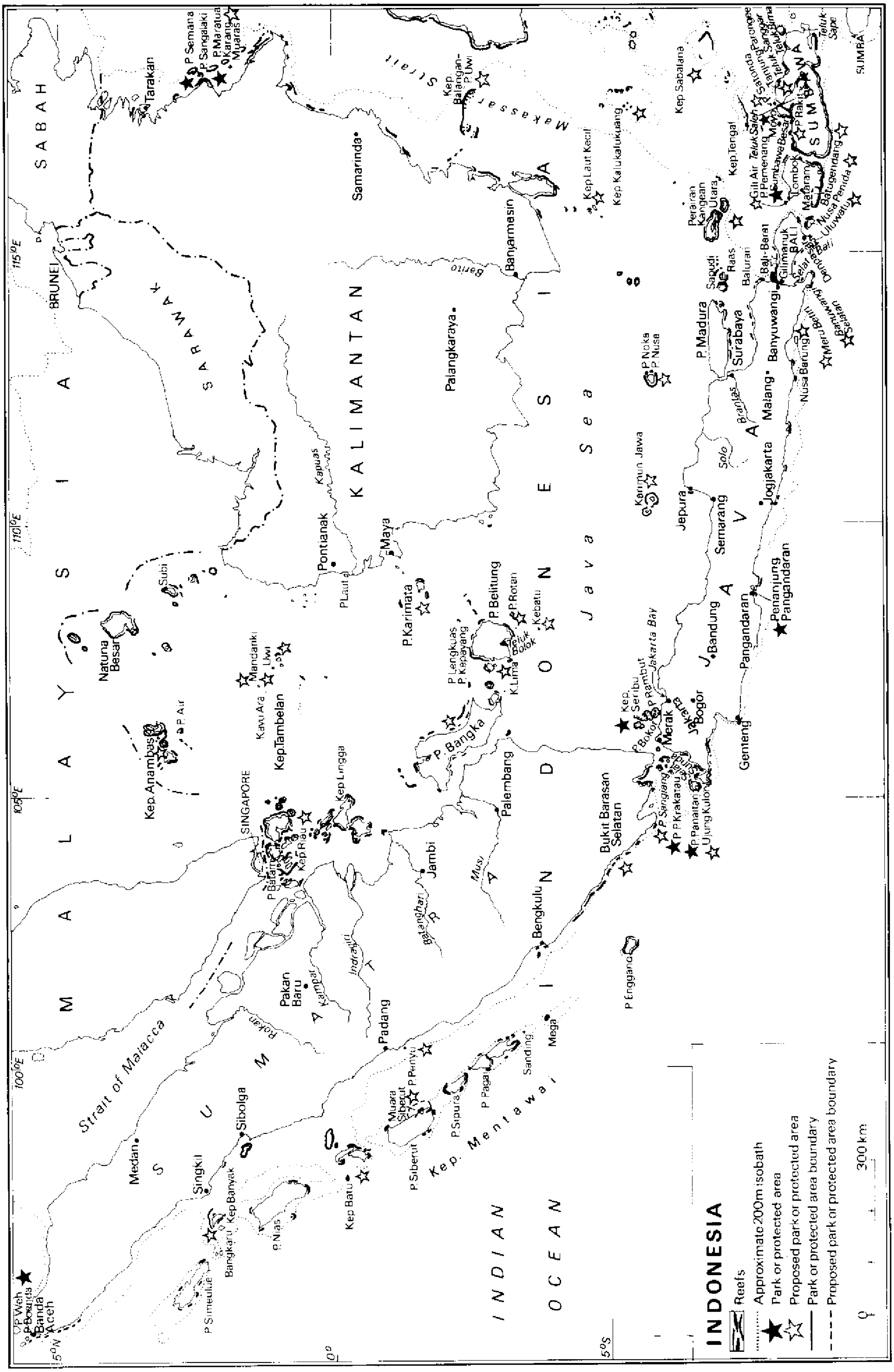
Indonesia, stretching from 6°N to 10°S and from 95° to 142°E, comprises over 13 600 islands and has a coastline of about 81 000 km. Sumatra, Java and Kalimantan lie on the Sunda shelf, the world's largest continental shelf, while Irian Jaya and its neighbouring islands are situated on the Sahul Shelf. Between these two shallow continental shelves is much deeper water and the island groups belonging to Sulawesi, Maluku and Nusa Tenggara (Soegiarto and Polunin, 1982; Soegiarto *et al.*, 1984). Sediments of the surrounding waters and associated marine environments are mapped in Salm and Halim (1984a).

The climate is equatorial and is modified by the monsoonal wind system. The north-west monsoon generally lasts from about December to February and the south-east monsoon from June to August. During the former, the wind blows eastward and brings heavy rainfall to most of the western part of the archipelago, particularly the Greater Sunda Islands of Sumatra, Java and Kalimantan. This lowers the salinity which, in the Java Sea, often approaches 30 ppt. In the south-east monsoon, these low salinity waters are transported back westward. The deep seas of central Indonesia (e.g. Flores, Banda, Seram, Maluku and Sulawesi Seas) generally remain extremely clear and favour reef development (Soegiarto *et al.*, 1984). Surface water temperatures are generally around 27-28°C, except where there are upwellings, as in the Straits of Makassar off south-west Sulawesi, south of Java, in the southern Bali Strait (Selat Bali), in the eastern Banda Sea, and probably in the Flores Sea and Maluku Sea west of Halmahera (Soegiarto and Polunin, 1982). Surface currents are mapped in Salm and Halim (1984a). Further information on oceanography is given in Soegiarto (1979a), Soegiarto and Birowo (1975) and Soegiarto and Polunin (1982); the latter provide a very useful summary and literature review.

An overview of the marine and littoral habitats of Indonesia is given in Salm (1984c). The most prolific reef development is towards the eastern end of the archipelago, particularly around islands in the deep clear seas of Central Indonesia, but reefs also occur off Sumatra and Java. Fringing reefs occur along the coasts of Sulawesi, Maluku (Moluccas), west and north Irian Jaya, Lesser Sundas, Bali, and some of the islands off the west and east coasts of Sumatra. Patch reefs are best developed in the Seribu and Sankarang (Spermonde) Islands and the best developed barrier reefs are found along the edge of the Sunda Shelf, east of Kalimantan, and around the Togian Islands, Central Sulawesi. There are few atolls, although Taka Bone Rate, in the Flores Sea, is the third largest in the world. Reefs are poorly developed where large rivers flow into the sea and cause high sedimentation and fluctuating salinity, such as around most of Kalimantan, the east coast of Sumatra, parts of Java and southern Irian Jaya. In these areas mangroves are well-developed. Reef distribution is mapped in Salm and Halim (1984a).

Reefs fringe the chain of islands lying off the west coast of Sumatra and a number were briefly described by Kohn (1971). These include a fringing reef on the west side of Pulau Boenda (Boenta) (5°33'N, 95°9'E; 3 km off Banda Aceh on the north-west tip of Sumatra), Pulau Penju (2°50'N, 95°56'E; off Simeulue (Simalur)), reefs around Pulau Pandjang (2°15'N, 97°24'E) and Pulau Melila (2°15'N, 97°25'E), in the Banyak (Banjak) group of islands, which lie 30-70 km west of Singkilbaru (Singkel), Pulau Bai (00°01'S, 98°31'E; in the Batu group between Nias and Siberut), and several reefs in the Mentawai islands including Pulau Siburu (Siboeroe) (1°59'S, 99°35'E; off the north tip of Sipora), an unnamed island in Veeckens Bay, south Pulau Pagai (3°14'S, 100°25'E), Pulau Stupai (Stoepai) off Sanding Island, the southernmost of the Mentawai group), Mega Island (3°59'S, 101°03'E; 60 km south of Sanding). Reefs in the Banyak and Batu island groups have important reef invertebrate resources (Usher, 1984). Reefs occur around Pulau Weh Marine Park (at the north-west tip of Sumatra) and in the areas proposed as reserves listed at the end of this section. Reefs do not occur on the northern part of the east coast of Sumatra but are widespread around the offshore islands to the south such as Kepulauan Riau, Pulau Bangka and Pulau Belitung, which are important for the collection of reef invertebrates, including *Tridacna gigas* (Usher, 1984) and Kepulauan Anambas and Kepulauan Tambelan to the east of Peninsula Malaysia. Very few of these reefs have been studied. The reef at Pulau Batam in Kepulauan Riau, 20 km from Singapore, was investigated in the course of an environmental impact study and was found to be relatively rich although damaged (Anon., 1983). Reefs occur in a number of proposed reserves in these areas (*see below*).

Reefs fringe parts of the southern coastline of Java and several islands in the Java Sea. Reefs in Kepulauan Seribu off Jakarta, Ujung Kulon "National Park" and adjacent islands on the western tip of Java, Penanjung Pangandaran Nature Reserve on the south coast and Baluran "National Park" on the north-east tip are described in separate accounts. Reefs are also found off the south-east tip of Java adjacent to Meru Betiri Wildlife Reserve and Nusa Barung Strict Nature Reserve (Usher, 1984). Umbgrove (1929a, b and c, 1939a) and Verwey (1929, 1931a and b) provide early descriptions of reefs in the Java Sea and Jakarta Bay (Bay of Batavia). Those in Jakarta Bay have been fairly extensively studied in recent years through research projects carried out by scientists from the University of Diponegoro, Semarang, and the University of Newcastle upon Tyne, U.K. (*see also account for* Kepulauan Seribu). Supriharyono (1985 and 1986) and Ongkosongo and Supriharyono (in press) studied the fringing reef at Bandengan Bay, near Jepara, north of Semarang. Reefs are also found in the proposed Karimunjawa Wildlife Reserve, a group of islands off the north coast (*see separate account*). The reefs around Pulau Raas and the Sapudi group of islands, off the eastern tip of Madura, near Surabaya, are described by Usher (1983). Reefs in the Kangean Islands, about 100 mi. (161 km) north of Bali and east of Madura, are described by Beudels *et al.* (1981) and De Longh *et al.* (n.d.) as not being particularly extensive or diverse.


INDONESIA
Reefs
Approximate 200m isobath
Park or protected area
Proposed park or protected area
Park or protected area boundary
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300 km
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K A L I M A N T A N
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Java Sea
INDIAN OCEAN
Strait of Malacca
Makassar Strait
Kep. Mentawai
Kep.Anambas
Natuna Besar
Kep.Tambelan
P. Bangka
P.Belitung
Kep. Seribu
Karimun Jawa
P.Madura
Samarinda
Tarakan
Banjarmasin
Palangkaraya
Pontianak
Jambi
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Malang
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BALI
Lombok
SUMBA
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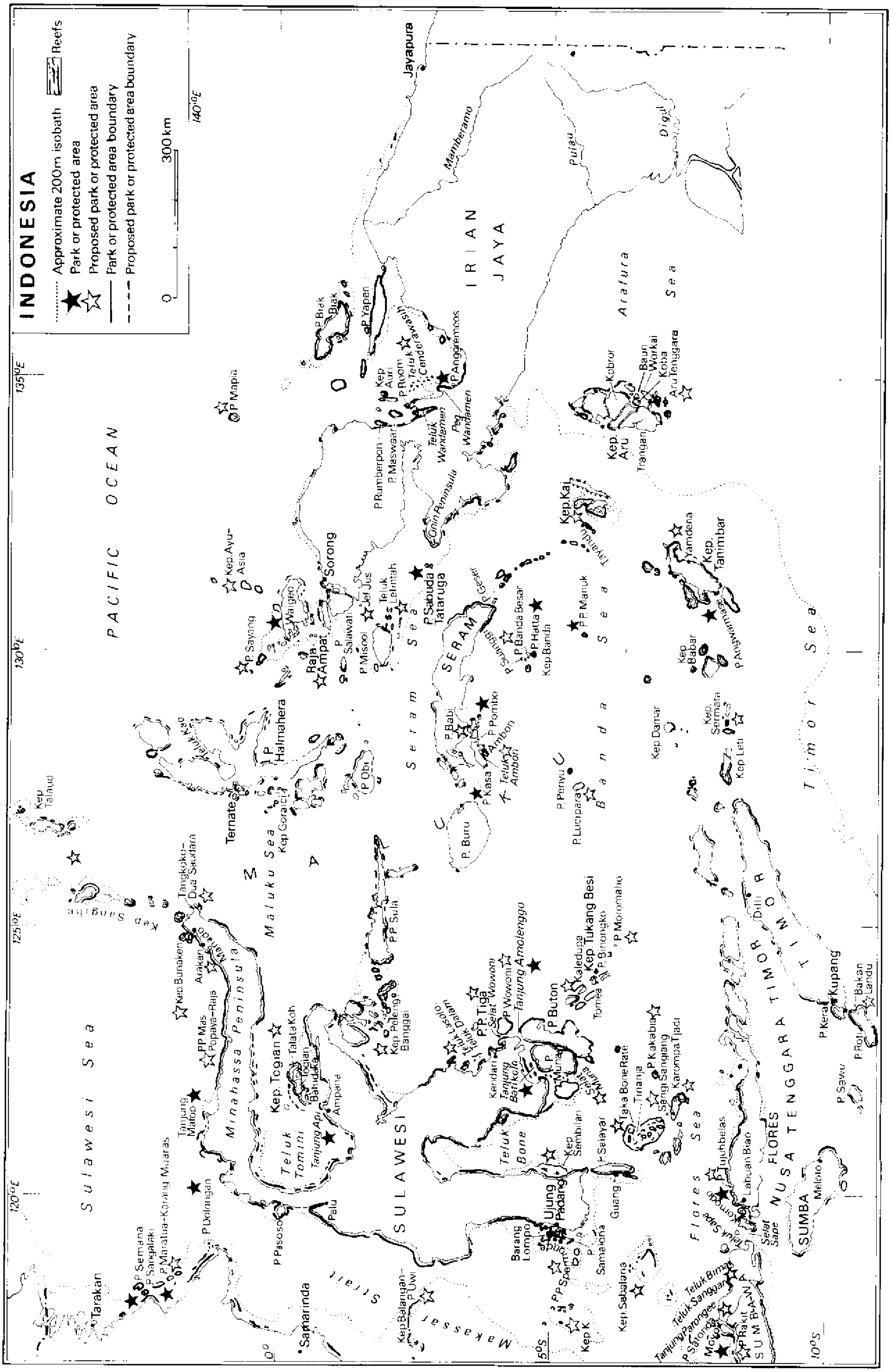
INDONESIA
Approximate 200m isobath
Reefs
Park or protected area
Proposed park or protected area
Park or protected area boundary
Proposed park or protected area boundary
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300 km
PACIFIC OCEAN
Sulawesi Sea
Makassar Strait
Flores Sea
Banda Sea
Seram Sea
Maluku Sea
Timor Sea
Arafura Sea
SULAWESI
IRIAN JAYA
SERAM
NUSA TENGGARA TIMOR
FLORES
SUMBA
SUMBAWA
P. Halmahera
P. Buru
P. Buton
P. Obi
Jayapura
Sorong
Ternate
Ujung Padang
Kupang
Dili
Palu
Samarinda
Tarakan
Manado
Ambon
Kep. Aru
Kep. Kai
Kep. Tanimbar
Kep. Tukang Besi
Kep. Togian
Raja Ampat
P. Biak
P. Yapen
Teluk Tomini
Teluk Bone
Minahassa Peninsula
Mamberamo
Digul
120°E
125°E
130°E
135°E
140°E
0°
5°S
10°S

The islands which make up Nusa Tenggara, to the east of Java, support many reefs. Those in Bali Barat "National Park" and Komodo "National Park" are described in separate accounts; reefs are also found within the proposed reserves for Nusa Tenggara, listed at the end of this section. The Snellius II Expedition looked at reefs around Komodo, Sumbawa and Sumba (Borel-Best *et al.*, 1985; Moll, 1986). Reefs in the bays of Sanggar and Teluk Moti on the north coast of Sumbawa were affected by the nearby Tambora Volcano which erupted in 1815; there are a few poorly developed reefs and some young rapidly growing reefs, 90% dominated by *Acropora* and with a few small massive corals such as *Porites*. Coral species diversity is high. Near Tangung Parongee, off the east flank of the volcano, there are well-developed reefs with high coral diversity and enormous (over 3 m in diameter) colonies of *Galaxea fascicularis*. Further east at the mouth of Teluk Bima, coral growth was well-developed down to 8 m depth, with spurs descending to 15 m where *Cyphastrea, Leptoseris* and *Anacropora* were abundant. *Oulastrea, Trachyphyllia* and *Lithophyllon* were found in shallower turbid water. Off the east coast of Sumba, a fringing reef south-east of Melolo was studied in turbid conditions. Reef condition was generally poor but branching *Acropora* and sediment-resistant species such as *Fungia actiniformis* and *Goniopora* spp. were present (Borel-Best *et al.*, 1985). A detailed description of the Fantome Bank in the Timor Sea is given by Preobrazhensky (1981).

No studies appear to have been carried out around the coast of Kalimantan but reefs occur in the proposed reserves listed at the end of this section. Most reefs are concentrated on the east coast, apart from those around Pulau Karimata, off the west coast.

In Sulawesi the main reef areas are off the north-east, eastern and south-western coastlines and a general description is given in Whitten *et al.* (1987). Most research has been carried out in Kepulauan Sankarang (the Spermonde Archipelago), on the west coast of Sulawesi off Ujung Pandang, and in the Togian Islands, off the north coast of central Sulawesi (*see separate accounts*), including the early studies of Umbgrove (1930a, 1939a and 1940). Studies in the Togian Islands have recommenced under a joint research programme between Indonesia and the Netherlands (Best, 1977; De Klerk; 1983; Moll, 1983; Wijsman-Best *et al.*, 1981). The Snellius II Expedition visited Tukang Besi, Kepulauan Sankarang, Taka Bone Rate and Salayar and adjacent islands off the south coast of Sulawesi (Borel-Best *et al.*, 1985). Reefs occur in the proposed reserves or reserve extensions in Kepulauan Bunaken, Arakan (north-eastern tip of Sulawesi, near Manado), Tukang Besi (a group of islands off south-east Sulawesi) and Taka Bona Rate (the largest atoll in Indonesia, and one of the largest in the world) (*see separate accounts*). The west coast of Salayar has some poorly developed fringing reefs; those around the islands of Guang and Bahuluang to the south were studied by Borel-Best *et al.* (1985) and Moll (1986). Reefs also occur within a number of proposed reserves listed at the end of this section. Roberts and Phipps (1986) briefly describe *Halimeda* bioherms along the edge of the Kalukalukuang Bank, off the south-western tip of Sulawesi.

Maluku has numerous islands with a total coastline of about 10 000 km, much of which is fringed by reef. Separate accounts are given for the reefs at Teluk Ambon (south-west Ambon, off the south-western tip of Seram), Pulau Pombo (off the north-western tip of Ambon), Pulau Kasa (north of Ambon), Pulau Banda (south of Seram), Pulau Penyu - Pulau Lucipara (in the middle of the Banda Sea, south of Seram) and Aru Tenggara (south-east of the Aru Archipelago, south of Irian Jaya); reefs occur in a number of proposed reserves, as listed at the end of this section.

In Irian Jaya, reef development is mostly restricted to islands off the north coast. Reefs in the Teluk Cenderawasih-Kepulauan Auri, Pulau Mapia (north coast of Irian Jaya) and Raja Ampat (north-west tip of Irian Jaya) proposed reserves are described in separate accounts; reefs are also found in the proposed reserves listed at the end of this section.

Soegiarto and Polunin (1982) and Polunin (1983) give a detailed overview of the marine environment and the former provides a history of marine research in the country. Sukarno (1972) reviews research in the early 1970s. Most work has been carried out in Kepulauan Seribu, on the north coast of Java and in south-west Sulawesi. Early studies on Indonesian coral reefs included Molengraaf (1930), Kuenen (1956), several by Umbgrove as mentioned above and also Umbgrove (1930b), and publications resulting from the Siboga Expedition of 1899-1900 (such as Boschma, 1923; Horst, 1921 and 1922) and the Snellius Expedition of 1929-1930. Under a joint Indonesia-Netherlands programme the Snellius II Expedition visited a number of reef areas in eastern Indonesia as described above and in the following accounts (Borel-Best, 1984; Borel-Best *et al.*, 1985; Moll, 1986; Van der Land and Sukarno, 1986). Further results of the expedition will be presented at a symposium in November 1987 (Borel-Best *in litt.*, 3.2.86). Soegiarto (1978) and Brown and Suprihayono (1985) provide a review of current marine science. A substantial number of reef surveys in Indonesia have been carried out since 1979 as part of a nationwide conservation strategy funded by Indonesia and international agencies, including IUCN, WWF, UNDP and FAO, in conjunction with the Directorate of Forest Protection and Nature Conservation (PHPA). Reef-related research is carried out at the Lembaga Oseanologi Nasional (LON) under the aegis of the Indonesia Institute of Sciences in Jakarta, and there are field stations in Pulau Seribu and Ambon. Sukarno (1984) describes some of the surveys carried out. The SEAMEO Regional Center for Tropical Biology (within BIOTROP) is reported to have some coral survey work underway (Gomez, 1980). Marine research is also carried out at the universities of Hasanuddin in Ujung Pandang, Diponegoro in Semarang (where there is a joint programme with the University of Newcastle upon Tyne, U.K.) and Pattimura in Ambon. The Institute of Marine Fishery Research (LPPL) also carries out reef-related research.

Reef-associated and other marine fauna, such as seabirds, turtles, Dugong *Dugong dugon* and Coconut Crabs *Birgus latro*, are mapped and described in Salm and Halim (1984a) and Salm (1984d). Turtle distribution is described in Schulz (1984), IUCN/WWF (1984) and Nuitja (in press); the Hawksbill *Eretmochelys imbricata* and Green Turtle *Chelonia mydas* are most common but the Leatherback *Dermochelys coriacea*, Olive Ridley *Lepidochelys olivacea* and Loggerhead *Caretta caretta* also occur and occasionally the Flatback *Chelonia depressa*. Faunal lists of reef-related species are given in

Soegiarto and Polunin (1982) and reef invertebrates are described in Usher (1984). Mangrove distribution is also mapped. De Korte (1984) provides a review of nesting seabirds in Indonesia.

**Reef Resources**

Coral reefs in Indonesia are extremely important for both subsistence and commercial fishing. Traditional uses of marine resources are described in Polunin (1984a and b), Soegiarto and Polunin (1982) (who provide a literature review) and Sya'rani and Willoughby (1985). Fisheries, including those associated with reefs, are mapped in Salm and Halim (1984a) and described by Soegiarto and Polunin (1982) and Sujastani (1980). The reef fishery in south-west Sulawesi is particularly important (Whitten *et al.*, 1987). The muro-ami technique is widely used for reef fish. There is an important ornamental fish trade, exports of marine organisms for the aquarium trade valuing US$60 742 in 1981. The main collecting areas are Java (Kepulauan Seribu, Jakarta Bay, Karang Hantu at Merak, Madura, Pelabuhan Ratu, Ujung Genteng, Pangandaran and Banyuwangi,), Sulawesi (Ujung Pandang and Minahassa), Bali (Gilimanuk area) and around Lombok (FAO, 1980; Salm and Halim, 1984a; Soegiarto and Polunin, 1982).

Usher (1984) provides a detailed account of the collection and use of reef invertebrates and Salm and Halim (1984a) map the distribution of important reef invertebrate fisheries. In most outlying areas local people are heavily dependent on a wide variety of reef and reef-associated animals for home consumption and trade, including turtles, fish, molluscs, crustaceans and echinoderms. Invertebrates may be collected by traditional itinerant freedivers, who operate mainly from Pulau Butung (Buton) (S.E. Sulawesi), S. Sulawesi (the Bugis people), Pulau Raas and Pulau Tonduk (both off Madura) and Kepulauan Aru (S.E. Maluku), professional divers (particularly for pearl oysters) or subsistence gatherers and fishermen. Mother-of-pearl, from *Trochus niloticus, Turbo marmoratus* and the pearl oysters *Pinctada maxima* and *P. margaritifera*, is one of the main exports but shells of a variety of other molluscs are taken for the ornamental shell trade. Giant clams are collected for processing into floor tiles. Coral reefs are a traditional source of limestone for building and for the production of lime. The invertebrate fishery associated with Pulau Raas is described by Usher (1983). Spiny lobster are collected throughout the country but major collecting areas are Pulau Seribu, Karimunjawa, Bali and off east Kalimantan where lobsters are frozen for export (Usher, 1984).

Algae are used for food and commercial purposes (Salm and Halim, 1984a; Soegiarto and Polunin, 1982). The turtle trade is extensive and is described in numerous publications; it is summarized in Salm and Halim (1984a) and discussed in IUCN/WWF (1984) and Schulz (1984).

Reef-related tourism is becoming increasingly important although at present, coral reefs in Indonesia play a relatively small part in the tourist industry, partly because many are inaccessible and facilities are few. Exceptions are the Bali reefs, those off Manado in northern Sulawesi (Whitten *et al.*, 1987), and the islands and reefs of the Seribu Archipelago in Java. Marine tourism has been examined by IDACIPTA (1979).

**Disturbances and Deficiencies**

Some of the reefs in the Java Sea were affected by the abnormal El Niño of 1983. Seawater temperatures rose as much as 5°C above normal and caused coral mortality in the Seribu Islands and Karimunjawa (*see separate accounts*) (Brown and Supriharyono, 1985; Suharsono, 1984). A summary of sources and locations of coral damage throughout Indonesia is given in Brown (in press).

The main causes of reef destruction and damage appear to be fish blasting, other inappropriate fishing methods and coral mining (Robinson *et al.*, 1981; Soegiarto and Polunin, 1982). Vast areas of coral on the Taka Bona Rate atoll have been destroyed, and nearly all the reefs surveyed in recent years show some degree of damage. Fish blasting is illegal but law enforcement is difficult. Dynamite fishing has damaged reefs in the Kangean Islands (De Longh *et al.*, n.d.) and in the vicinity of Ujung Pandang (Burbridge and Maragos, 1985). Fishermen also cause damage by dragging nets over reefs, walking on the coral, poling their boats and dropping anchor on delicate growths, and using cyanide (Soegiarto and Polunin, 1982). Similar damage has been reported from Pulau Raas, off the north coast of Java (Usher, 1983) and at many of the sites described in the following accounts.

Increased tourism has caused a greater demand for coral reef curios, and contributed to overexploitation of coral reef resources, including valuable commercial species of fish and molluscs as well as turtles, dugongs and crocodiles. Usher (1984) describes a number of reef invertebrates which are considered threatened through overcollecting, including the Giant Clams *Tridacna gigas, T. derasa* and *Hippopus porcellanus*, the Giant Triton *Charonia tritonis* and the pearl oyster *Pinctada maxima*. The problems of overfishing in South Sulawesi are described by Davies and Mustafa (1984) and damage caused by the ornamental fish trade is described by FAO (1980) and Robinson *et al.* (1981). The impact of pollution on the fishing industry is described by Soegiarto (1977a).

Considerable damage has been caused as a result of mining and collection of coral for limestone and production of lime since early this century (Hardenberg, 1939; Umbgrove, 1947). It is a labour-intensive cottage industry; dead coral is taken from back reefs and living coral from deeper reef faces. Small pieces are used to make lime and large pieces are used directly as building materials (Robinson *et al.*, 1981). Reefs around Jakarta and Ujung Pandang, and in Bali and east Java have been particularly seriously affected (UNDP/FAO, 1979a; Knox and Miyabara, 1984; Sya'rani and Willoughby, 1985). In Jakarta Bay, the coral islands of Ubi Besar and Nirwana have been significantly eroded as a result of coral mining and Air Kecil and Ubi Kecil have now disappeared altogether (Ongkosongo, 1981; Ongkosongo and Sukarno, in press). In Bali there are several hundred limestone kilns and mining for coral has caused noticeable turbidity of the water and erosion of the beach. Reefs at the popular tourist resort of Sanur have been damaged and there are fears that the resorts being developed at Nusa Dua and Jembrana could be affected (Anon., 1980; Ongkosongo, 1981). A study using remote sensing has shown significant beach erosion in the east, near Pandekan Bay, caused by increased wave action following coral removal (Praseno and Sukarno, 1977).

Development of tourist facilities in the Seribu Archipelago has led to reef damage as a result of bad planning, for example in the construction of boat harbours and breakwaters. Reefs close to centres of urban and industrial development, such as those adjacent to Jakarta, Ambon and Ujung Pandang, are threatened by sedimentation and pollution, but few data are available on actual damage. The reefs off the east coast of Sumba were found to be in poor condition, probably due to human activities. Reefs off Salayar, off the south coast of Sulawesi, are in poor condition due to sedimentation resulting from erosion and overfishing (Borel-Best *et al.*, 1985). The reefs around Pulau Batam, in Kepulauan Riau, Sumatra, may be affected by the proposed development of a free port zone (Anon., 1983). Sedimentation is probably becoming a problem in several areas including the north coast of Java, off Padang in west Sumatra, and in east Bali (Soegiarto and Polunin, 1982). Reefs at Bandengan Bay, near Jepara on the north coast of Java, are subject to very heavy sediment loading during the wet monsoon period (Supriharyono, 1985 and 1986). Mangroves have been seriously damaged throughout much of Indonesia and are discussed in numerous publications such as Abdullah (1982), Soegiarto and Polunin (1982), Soemodihardjo (1984) and Soegiarto (1984).

In 1976, 70% of the Indonesian continental shelf was concessioned to companies for oil exploration and there is considerable potential for serious oil pollution. Oil field developments are concentrated mainly near Java, Irian Jaya and Sumatra, but may spread to the west coast of Sulawesi (Bilal and Kuhnhold, 1980; Soegiarto, 1977b). Sites which are particularly vulnerable to potential oil spills are mapped in Salm and Halim (1984a) and Soegiarto and Polunin (1982) give an account of sources of marine pollution. In 1985 a Unesco workshop on the effects of pollution on coral reefs was held in Kepulauan Seribu (Brown in press). Reef degradation decreases from the Bay of Jakarta seawards through the islands, presumably at least partly due to the lessening impact of pollution and human activities (Moll and Suharsono, in press).

**Legislation and Management**

Marine conservation and coral reef management in Indonesia are discussed by Robinson *et al.* (1981), Salm *et al.* (1982c), Soegiarto (1979b) and Soegiarto *et al.* (1984). In 1983 a Sub-Directorate of Marine Conservation was established within the Directorate General of Forest Protection and Nature Conservation (PHPA) to manage the expanded marine programme and to help PHPA in the management of marine protected areas. In the early 1980s, a Government policy was declared to protect 10 million ha of marine and littoral areas by 1990 and 30 million ha by the year 2000. A Marine Conservation Data Atlas was produced as the foundation for planning a full scale system of marine protected areas (Salm and Halim, 1984a) and a six-volume system plan covering marine conservation policy, law, species and habitat conservation and protected areas was developed (Salm, 1984a).

There are a number of traditional practices or "adat" which control collection of marine resources. For example, on Pulau Hatta, in the Banda Sea, collection of trochus is controlled by the village headman and in several areas, especially Maluku, systems called "sasi" control local fishing practices. However, many of these have been lost (Usher, 1984). Traditional conservation practices are described in detail by Polunin (1984a and b), Soegiarto and Polunin (1982) and Sya'rani and Willoughby (1985).

The protection of marine resources is possible by decree of the Minister of Forestry under two ordinances carried over from colonial times: Dierenbescherming Ordannantie (Stb. 1927:34; Stb. 1931:134, 266; Stb. 1932:28; Stb. 1935:513) and Natuurbescherminge Ordannantie (Stb. 1941:167). A list of protected marine species is given in Salm (1984d). Exploitation of live corals, including mining, is restricted, and may only be carried out by permit under a number of early Dutch laws, still operative but rarely enforced. Provincial regulations in Kepulauan Seribu control coral and sand mining. Destructive methods of fishing, such as the use of explosives and poisons, are forbidden by the Fishery Ordinance 1920, which also prohibits harvest of pearls and sponges. There are a variety of other fishing regulations listed in Soegiarto and Polunin (1982) and Salm and Halim (1984b). Loggerhead, Leatherback and Olive Ridley Turtles are completely protected by Ministerial Decree but Green and Hawksbills are unprotected (Soegiarto, *et al.*, 1984). Dugong and the Saltwater Crocodile *Crocodylus novaeguinae* are officially protected. Export of turtle products is prohibited under CITES regulations, to which Indonesia is a signatory, but the regulations are incompletely enforced (Salm and Halim, 1984a).

PHPA has the mandate to protect, conserve and manage coastal and marine habitats valuable to fisheries and tourism, and is responsible for the establishment and management of terrestrial and marine protected areas and protection of species. Specific regulations can be applied to certain areas, and reserves, sanctuaries and parks have been declared at provincial level by Ministerial Decrees. These decrees prohibit various activities and/or require issue of permits (UNDP/FAO, 1982f).

The classification of marine protected areas and regulations pertaining to them have yet to become law but a number of different types of reserves are already being used: Marine National Parks (Taman Nasional Laut), Strict Nature Reserve/Zone (Cagar Alam), Wilderness Reserve/Zone (Suaka Margasatwa), Traditional Use Zone, Intensive Use Zone, Marine Multiple Use Reserve and Marine Park (used for areas where the status has not yet been defined) (Salm, 1984a; Salm and Halim, 1984a, b and c; Usher, 1984). There are also Recreation Parks (Taman Wisata) (Soegiarto and Polunin, 1982).

Several reserves, sanctuaries and parks which include coral reefs as a major or minor element have been declared and are listed below. Salm (1984c) analyses the extent to which these areas provide protection for different types of reef. The four National Parks, although declared, are not yet legal entities as the legislation enabling their establishment is still lacking. In the following accounts they have been designated as "proposed" National Parks. Management plans have been produced for some of the sites through the IUCN/WWF programme but policies are not always effectively implemented. As a result, the reefs in some of the protected areas have continued to be degraded (UNDP/FAO, 1982f). (* = described in a separate account):

*Sumatra*

- Pulau Weh Marine Park: established 1982; 6°0'N, 95°30'E, off the extreme north-westerly tip of Sumatra; 3000 ha of islands and fringing reefs.

*Java*

- Baluran "National Park"*
- Kepulauan Seribu Strict Nature Reserve/"Marine Park"*
- Penanjung Pangandaran Nature Reserve*
- Ujung Kulon "National Park"*

*Nusa Tenggara*

- Bali Barat "National Park"*
- Komodo Biosphere Reserve and "National Park"*

*Kalimantan*

- Pulau Sangalaki Marine Park: established 1982; 2°05'N, 118°15'E, 60 km east of north-east Kalimantan and 160 km south-east of Tarakan; island with fringing reef; nesting site for Green and Hawksbill Turtles (Salm and Halim, 1984a); Bugis and Butungese itinerant divers collect reef invertebrates (Usher, 1984).
- Pulau Semama Wildlife Reserve: established 1982; 2°05'N, 118°15'E, just north-west of Pulau Sangalaki (total area of both reserves 65 ha (IUCN, in prep.)); island with fringing reef; nesting site for Green and Hawksbill Turtles (Salm and Halim, 1984a); Bugis and Butungese itinerant divers collect reef invertebrates (Usher, 1984).

*Maluku*

- Pulau Angwarmase Strict Nature Reserve: established 1978; 7°55'S, 131°20'E, south-east Maluku, off south-west coast of Tanimbar; 800 ha; island with sandy beaches and coral reef (Salm and Halim, 1984a).
- Pulau Banda Strict Nature Reserve/Marine Park*
- Pulau Kasa Wildlife Reserve/Marine Park*
- Pulau Pombo Strict Nature Reserve/Marine Park*

*Sulawesi*

- Tangkoko-Dua Saudara Strict Nature Reserve*
- Tanjung Amolenggo Wildlife Reserve: established 1975; 4°30'S, 123°0'E, on mainland coast of extreme south-east tip of Sulawesi Tenggara; 850 ha; beach forest and coral reef (Salm and Halim, 1984a).
- Tanjung Batikolo (Baticolo) Wildlife Reserve: established 1980; 4°35'S, 122°55'E, on mainland coast at extreme south-east tip of Sulawesi Tenggara; 5500 ha; beach vegetation and coral reef (Salm and Halim, 1984a).

*Irian Jaya*

- Pulau Sabuda-Pulau Tataruga Wildlife Reserve: established 1980; 2°30'S, 130°50'E, between Irian Jaya and Seram; 450 ha, including 50 ha coral reef (Soegiarto *et al.*, 1984); Green Turtles nest on islands (Salm and Halim, 1984a); important reef invertebrate resources (Usher, 1984).

**Recommendations**

The marine systems plan described above provides the basis for continuing a marine programme in Indonesia. A policy specifically for coral reefs has been drafted by Salm (1984c) which covers the control of all damaging activities on or near reefs. Guidelines for the establishment of coral reef reserves were drawn up by UNDP/FAO (1982g) and Salm (1984b and c) outlines a marine protected areas policy and discusses implementation of the marine protected areas plan. The need for government involvement in coral reef management is described in Burbridge and Maragos (1985). An earlier action plan for the marine environment by Soegiarto and Polunin (1982) included recommendations for improved management of the fisheries and a discussion of strategies for the management of reefs and other critical marine habitats.

Indonesia now has an ambitious programme for designating marine protected areas. As far as coral reefs are concerned, the aim of the protected areas plan is to establish a system of protected areas which are linked by current corridors, to ensure larval dispersal of reef species. Multiple use protected areas have been proposed for large, relatively undisturbed reef areas far from the main islands; these tend to have small human populations which rely heavily on reef resources. Such reserves can be zoned for strict protection of valuable areas, appropriate tourism development and fishing by residents using approved methods. Itinerant fishermen and collectors of mother-of-pearl should be prohibited. Management shoud be largely entrusted to the heads of local villages with a low level of supervision by PHPA (Salm, 1984c). A detailed discussion of the different categories proposed for marine protected areas is given in Salm and Halim (1984c).

A complete listing of the proposed marine protected areas and seaward extensions of terrestrial protected areas (over 100 in total) is given in Salm and Halim (1984a and c). Their implementation is considered an urgent priority under the Corbett Action Plan for Protected Areas of the Indomalayan Realm (Thorsell, 1985). A priority order for implementing the area (first to fourth) has been suggested by Salm and Halim (1984a). The following areas include reefs . (* = described in a separate account):

*Sumatra*

- Kayu Ara Strict Marine Reserve: island north of Kepulauan Tambelan; 5000 ha; reef, nesting seabirds; Second Order Priority (Salm and Halim, 1984a and c).
- Kebatu Strict Marine Reserve: south of Pulau Belitung; 5000 ha; reefs, nesting seabirds; Third Order Priority (Salm and Halim, 1984a and c).
- Kepulauan Anambas Selatan Multiple Use Management Area: east of Peninsular Malaysia and north of Kepulauan Tambelan; 200 000 ha; reefs, nesting turtles; Third Order Priority (Salm and Halim, 1984a and c).

- Kepulauan Banyak-Bangkaru Multiple Use Management Area: west of Singkil; 200 000 ha; reefs, turtles; Second Order Priority (Salm and Halim, 1984a and c).
- Kepulauan Riau Selatan-Lingga Utara Multiple Use Management Area: east coast, south of Singapore; 200 000 ha; reefs, mangrove islands, nesting turtles; Second Order Priority (Salm and Halim, 1984a and c).
- Mandariki Strict Marine Reserve: south-east of Kayu Ara; 5000 ha; reef, nesting seabirds; Second Order Priority (Salm and Halim, 1984a and c).
- Muara Siberut Strict Nature Reserve/Marine Multiple Use Reserve: 1°30'S, 99°25'E, off east coast of Siberut in Mentawai Archipelago, 15 227 ha; five islands with coral reefs, mangroves, dolphins, trochus and Giant Clams (Usher, 1984); Second Order Priority (Salm and Halim, 1984a and c).
- Perairan Kepulauan Batu Multiple Use Management Area: north of Siberut; 200 000 ha; reefs, giant clams, nesting turtles; Second Order Priority (Salm and Halim, 1984a and c).
- Pulau Bangka Timur Multiple Use Management Area: east coast of Pulau Bangka; 200 000 ha; reefs, nesting turtles; Third Order Priority (Salm and Halim, 1984a and c).
- Pulau Lengkuas-Pulau Kepayang Managed Marine Reserve: north coast of Pulau Belitung; 25 000 ha; reefs, nesting turtles; Second Order Priority (Salm and Halim, 1984a and c).
- Pulau Penyu Strict Marine Reserve: south of Padang; 15 000 ha; reefs, giant clams, nesting turtles; First Order Priority (Salm and Halim, 1984 a and c).
- Pulau Segamat Strict Marine Reserve: (location not known); 15 700 ha; reef, nesting turtles (Salm and Halim, 1984c).
- Tambelan-Uwi Multiple Use Management Area: west of Kalimantan; 50 000 ha; reefs, nesting seabirds and turtles; Second Order Priority (Salm and Halim, 1984a and c).
- Perairan Manggar Tenggara-Pulau Rotan Multiple Use Management Area: south-east coast of Pulau Belitung; 100 000 ha; reefs, nesting turtles; Second Order Priority (Salm and Halim, 1984a and c).
- Teluk Bolok-Kepulauan Lima Multiple Use Management Area: south-west coast of Pulau Belitung; 100 000 ha; reefs, nesting turtles; Second Order Priority (Salm and Halim, 1984a and c).

*Java*

- Karimunjawa Wildlife Reserve*
- Perairan Kangean Utara Multiple Use Management Area: north of Bali; 100 000 ha; reefs (but not rich), seagrass, turtles, seabirds; First Order Priority (Salm and Halim, 1984a and c).
- Pulau Sangiang Protected Seascape: off the western tip of Java; 3000 ha; reefs; recreational value; Third Order Priority (Salm and Halim, 1984a and c).

*Nusa Tenggara*

- Bakau Landu Managed Marine Reserve: north-east coast of Rote (Roti); 1000 ha; cays, reefs, mangroves; Third Order Priority (Salm and Halim, 1984a and c).
- Batugendang Wildlife Reserve: 10°50'S, 115°50'E, south-west tip of Lombok; 10 000 ha; cliffs, coral reefs, nesting seabirds; First Order Priority (Salm and Halim, 1984a and c).
- Gili Air - Pulau Pemenang Wildlife Reserve: 9°55'S, 116°0'E, north-west Lombok; 2000 ha; islets and coral reefs; Second Order Priority (Salm and Halim, 1984a and c).
- Kepulauan Tujuhbelas Wildife Reserve: 8°25'S, 120°10'E, north-west tip of Flores; 5000 ha; coral reef and islets; Second Order Priority (Salm and Halim, 1984a and c).
- Nusa Penida Marine Park: between Bali and Lombok; 5000 ha; reefs, seabirds; First Order Priority (Salm and Halim, 1984a and c).
- Pulau Rakit Marine Recreation Park: 8°35'S, 118°0'E, in Teluk Saleh, north coast of Sumbawa; 2000 ha; coral island with beach forest and reef; Fourth Order Priority (Salm and Halim, 1984a and c).
- Pulau Satonda Marine Recreation Park: 8°10'S, 117°45'E, north coast of central Sumbawa; 1000 ha (?22 000 ha); small volcanic island with brackish lake, reefs and dense seagrass beds; Third Order Priority (Salm and Halim, 1984a and c).
- Teluk Kupang-Pulau Kera Marine Recreation Park: south-west Timor; 10°02'S, 123°30'E; 8 ha (?100 000 ha); sand cay, coral reefs, dugong; Third Order Priority (Salm and Halim, 1984a and c).
- Uluwatu Strict Marine Reserve; southern tip of Bali; 2500 ha; reefs, seabirds; Second Order Priority (Salm and Halim, 1984a and c).

*Kalimantan*

- Karimata Strict Nature Reserve: 1°30'S, 109°0'E, south-west of Maya on the south-west coast of Kalimantan; area to cover 77 000 ha (?87 000 ha), including 10 000 ha of coral reef and islands; Fourth Order Priority (Soegiarto *et al.*, 1984; Salm and Halim, 1984a and c).
- Kepulauan Laut Kecil Multiple Use Management Area: off the south-west tip of Kalimantan; 200 000 ha; reefs, nesting turtles; Second Order Priority (Salm and Halim, 1984a and c).
- Kepulauan Balangan-Pulau Uwi Multiple Use Management Area: between Kalimantan and Sulawesi; 200 000 ha; patch and barrier reefs, turtles; Third Order Priority (Salm and Halim, 1984a and c).
- Pulau Maratua-Karang Muaras Strict Nature Reserve: 1°50'-2°10'N, 118°30'-118°55'E, 160 km south-east of Tarakan, 80-90 km off north-east coast of Kalimantan; 100 000 ha; islands and 10 000 ha of coral reef (Soegiarto *et al.*, 1984); nesting turtles; Bugis and Butungese itinerant divers collect reef invertebrates (Usher, 1984); Second Order Priority (Salm and Halim, 1984a and c).

*Maluku*

- Aru Tenggara Strict Nature Reserve/Marine Park*
- Kepulauan Kai Barat-Tayandu Marine Multiple-Use Reserve: 5°30'S, 133°0'E, 125 km south of Irian Jaya, south-east Maluku; 200 000 ha; islands, coral reefs, nesting sea birds, possibly Coconut Crabs; First Order Priority (Salm and Halim, 1984a and c).
- Kepulauan Sermata Barat Multiple Use Management Area: east of Timor; 200 000 ha; atoll and fringing reefs, giant clams; First Order Priority (Salm and Halim, 1984a and c).

- Pulau Babi Marine Park (*see account for* Pulau Kasa).
- Pulau Penyu-Pulau Lucipara Strict Nature Reserve*
- Pulau Suanggi Strict Marine Reserve: (*see account for* P. Banda)
- Teluk Ambon Marine Multiple-Use Reserve*
- Yamdena Strict Marine Reserve: on Tanimbar; 10 000 ha; reefs, mangroves, coastal swamps; Fourth Order Priority (Salm and Halim, 1984a and c).

*Sulawesi*

- Arakan Wildlife Reserve*
- Karompa Tjadi Strict Marine Reserve: south-east of Taka Bone Rate; 15 000 ha; reefs, nesting seabirds; First Order Priority (Salm and Halim, 1984a and c).
- Kepulauan Bunaken Marine Recreation Park*
- Kepulauan Kalukalukuang Multiple Use Management Area; west of Kepulauan Sankarang; 100 000 ha; reefs, turtles; Third Order Priority (Salm and Halim, 1984a and c).
- Kepulauan Peleng-Banggai Strict Nature Reserve or Multiple Use Management Area: 1°50'S, 123°14'E, south of Pulau Peleng, eastern central Sulawesi; 150 000 ha; islands, reefs, Giant Clams, Dugong, possibly Coconut Crabs; nesting site for Green Turtles (Salm and Halim, 1984a); major *Pinctada maxima* fishery; trochus and sea cucumbers collected; Japanese-run pearl oyster farm (Usher, 1984); First Order Priority (Salm and Halim, 1984a and c).
- Kepulauan Sangihe-Talaud Wildlife Reserve or Multiple Use Management Area: 3°45'N, 126°35'E, 250 km north-east Sulawesi; 150 000 ha; islands, coral reefs, possibly Coconut Crabs; Third Order Priority (Salm and Halim, 1984a and c).
- Kepulauan Sembilan Managed Marine Reserve; south-west Sulawesi; 20 000 ha; barrier, fringing and patch reefs, turtles; Second Order Priority (Salm and Halim, 1984a and c).
- Kepulauan Tengah-Kepulauan Sabalana Multiple Use Management Area: west of Taka Bone Rate; 500 000 ha; reefs, turtles; Third Order Priority (Salm and Halim, 1984a and c).
- Kepulauan Togian Marine Multiple Use Reserve*
- Pulau Kakabia (Kawi-Kawi) Strict Nature Reserve: 6°55'S, 122°30'E; Flores Sea between Sulawesi and north-east coast of Flores; 15 000 ha; islands, reefs, seabirds, turtles; First Order Priority (Salm and Halim, 1984a).
- Pulau Maromaho Strict Marine Reserve: south-east of Tukang Besi; 15 000 ha; reefs, nesting seabirds; First Order Priority (Salm and Halim, 1984a and c).
- Pulau Pasoso Wildlife Reserve: 0°10'N, 119°45'E, north-west Sulawesi; 15 000 ha; reef-fringed limestone island; nesting Green Turtles; First Order Priority (Salm and Halim, 1984a and c).
- Pulau Pulau Spermonde-Pulau Samalona Marine National Park*
- Pulau Pulau Tiga Wildlife Reserve: 3°50'S, 123°15'E, 45 km north of Pulau Wowoni, east coast of south-eastern Sulawesi; 15 000 ha; islands, reefs, Green and Hawksbill Turtles; Third Order Priority (Salm and Halim, 1984a and c).
- Sangi Sangiang Strict Marine Reserve: south-east of Taka Bone Rate; 15 000 ha; reefs, nesting seabirds; First Priority Order (Salm and Halim, 1984a and c).
- Selat Muna Wildlife Reserve: 5°05'S, 122°05'E, off west coast of Muna, an island off the south-east tip of Sulawesi Tenggara; 5000 ha; coral island, reefs, dugong, turtles, mangroves (Salm and Halim, 1984a); major *Pinctada maxima* fishery at nearby Butung (Usher, 1984); Fourth Order Priority (Salm and Halim, 1984a and c).
- Selat Wowoni Strict Nature Reserve: 4°10'S, 123°05'E, between Pulau Wowoni and eastern coast of south-east Sulawesil; 25 000 ha; reefs, dugong (Soegiarto *et al.*, 1984); Fourth Order Priority (Salm and Halim, 1984a and c).
- Taka Bone Rate Wildlife Reserve*
- Teluk Lasolo-Teluk Dalam Wildlife Reserve: 3°30'S, 122°30'E, east coast of Sulawesi Tenggara; 50 000 ha; reefs, dugong, turtles; Second Order Priority (Salm and Halim, 1984a and c).
- Tukang Besi Wildlife Reserve*

*Irian Jaya*

- Jef Jus Strict Marine Reserve: off the north-west tip of Irian Jaya; 5000 ha; reefs, nesting seabirds; Second Order Priority (Salm and Halim, 1984a and c).
- Kepulauan Ayu-Asia Wildlife Reserve: 0°50'-1°25'N, 131°16'E, 130-220 km north of western tip of Irian Jaya; 904 ha (Soegiarto *et al.*, 1982) or 10 000 ha (?); two atolls with associated reefs, nesting Green and Hawksbill Turtles, major reef invertebrate resources (Usher, 1984); Third Order Priority (Salm and Halim, 1984a and c).
- Pulau Mapia Wildlife Reserve*
- Pulau Sayang Managed Marine Reserve: north-west of Pulau Waigeo; 10 000 ha; reef, nesting turtles; Third Order Priority (Salm and Halim, 1984a and c).
- Raja Ampat Wildlife Reserve*
- Teluk Cenderawasih-Kepulauan Auri Wildlife Reserve*
- Teluk Lelintah Wildlife Reserve: south-east coast of Pulau Misool; 75 000 ha; limestone islets, reefs, possibly Coconut Crabs; Second Order Priority (Salm and Halim, 1984a).

A number of extensions have been proposed for existing terrestrial protected areas in order to include further areas of reefs:

*Sumatra*

- Bukit Barisan Selatan: south-west coast; mangroves, swamp forest, sandy beaches, nesting turtles; declared a Wildlife Reserve and National Park under decrees in 1935 and 1982; Fourth Order Priority (Salm and Halim, 1984a and c).
- Pulau Weh: (*see above*)

*Java*

- Baluran*
- Banyuwangi Selatan: south coast; nesting turtles; declared a wildlife reserve in 1939; Fourth Order Priority (Salm and Halim, 1984a and c).
- Krakatau: (*see account for* Ujung Kulon)
- Meru Betiri: south-east coast; beaches, mangroves, nesting turtles; declared a Wildlife Reserve and National Park under decrees in 1972 and 1982; extension to cover 50 000 ha reef; Second Order Priority (Salm and Halim, 1984a and c)
- Nusa Barung: limestone island off south coast with caves and beaches, nesting turtles and seabirds;

declared a Strict Nature Reserve 1920; extension to cover 6100 ha reef (Usher, 1984); Second Order Priority (Salm and Halim, 1984a and c).
- Penanjung Pangandaran*
- Pulau Bokor: (*see account for* Kepulauan Seribu)
- Pulau Noko-Pulau Nusa; two small islets off north coast; nesting seabirds; declared a Strict Nature Reserve 1926; Fourth Order Priority (Salm and Halim, 1984a and c)
- Pulau Rakit: (*see account for* Kepulauan Seribu)
- Ujung Kulon-Peucang-Panaitan: (*see account for* Ujung Kulon)

*Nusa Tenggara*

- Bali-Barat*
- Komodo-Padar-Rinca (*see account for* Komodo Biosphere Reserve)
- Pulau Moyo Wildlife Reserve*

*Kalimantan*

- Pulau Semama-Pulau Sangalaki (*see above*)

*Sulawesi*

- Pulau Dolongan: north coast; rocky island, nesting turtles; declared a Wildlife reserve 1981; Third Order Priority (Salm and Halim, 1984a and c).
- Pulau Pulau Mas-Popaya-Raja: north coast; Popaya and Mas are sandy with nesting green turtles; Raja is rocky with roosting seabirds; declared a Strict Nature Reserve 1939; Fourth Order Priority (Salm and Halim, 1984a and c).
- Tanjung Amolenggo (*see above*)
- Tanjung Api Strict Nature Reserve*
- Tanjung Batikolo (*see above*)
- Tanjung Matop: north coast; coral beaches, nesting turtles; declared a Wildlife Reserve 1981; Third Order Priority (Salm and Halim, 1984a and c).
- Tangkoko-Dua*

*Maluku*

- Pulau Manuk: south of Pulau Banda; oceanic volcano; nesting seabirds; declared a Wildlife Reserve 1981; Second Order Priority (Salm and Halim, 1984a and c)
- Pulau Angwarmase (*see above*)

*Irian Jaya*

- Pulau Waigeo Barat (*see account for* Raja Ampat)
- Pulau Sabuda-Tataruga (*see above*)

There is a proposal for regional co-operation in the establishment of a reserve to cover the reefs and marine resources of north-east Kalimantan, Sabah and the Turtle Islands in Philippine waters (Salm *et al.*, 1982c; Soegiarto *et al.*, 1982).

The highest priority areas for protection are considered to by Teluk Cenderawasih, Kepulauan Togian, Taka Bone Rate, Kepulauan Bunaken and Karimunjawa (Salm, 1984c). Reefs off the north coast of Irian Jaya are probably the least disturbed in the country and therefore need particular attention. Petocz (1985) describes the protected area system for Irian Jaya. Maluku is probably the least known region for its reefs but is of particular interest and urgently requires surveying, having important populations of seabirds, turtles, dugongs, reef invertebrates and being a centre of marine product trade, a whale migration corridor and having major reef areas. Areas which are considered high priorities for survey work include Nusa Tenggara, south Maluku, Kai, Tanimbar, western Irian Jaya, Halmahera, Tukang Besi, eastern Kalimantan, Mentawai, Bangka-Belitung and Kepulauan Riau (Salm, 1984c).

In areas where the reefs are not considered sufficiently important or where they have already been damaged, reserves may not be appropriate and in such cases emphasis should be placed on the development of educational programmes, for the public, coastal people and also PHPA staff, to promote the conservation of reef resources. For example, this should be a priority in the Sapudi group of islands (Usher, 1983) and in the Kangean Islands (Beudels *et al.*, 1981).

Usher (1984) gives recommendations for the protection and management of reef invertebrates. Areas which should be surveyed as soon as possible include the east (Kepulauan Riau, Pulau Bangka, Pulau Belitung) and west (Kepulauan Batu, Kepulauan Banyak) coast of Sumatra; the east coast of Kalimantan (Pulau Semama-Sengalaki, Pulau Maratua); central Sulawesi (Kepulauan Banggai); south-east Sulawesi (Pulau Muna, Kepulauan Besi); Nusa Tenggara (Teluk Sape and Teluk Waworadu on Sumbawa, Waiwerang, Pulau Sawu); Maluku (Teluk Kau on Halmahera), Kepulauan Goraici, Pulau Obi, Pulau Pulau Sula, Pulau Geser (East Seram), Kepulauan Kai, Kepulauan Penyu-Lucipara, Kepulauan Tanimbar, Kepulauan Babar-Leti-Damar); and Irian Jaya (Kepulauan Asia-Ayu, Kepulauan Sabuda-Tataruga, Kepulauan Raja Ampat, Pulau Sayang, Pulau Misool, Onin Peninsular). The potential for translocation of threatened species should be investigated; at present this is probably only feasible for the Giant Clam *Tridacna gigas* which could be introduced into Kepulauan Seribu Marine National Park, the LON research station at Pulau Pari or the Pulau Pombo Marine Park. Usher (1984) also provides recommendations for mariculture programmes, for example for *T. gigas* and other molluscs at Seribu or Ambon, and for further research on reef invertebrates.

Further information on reef-associated species is given in Salm (1984d), includes lists of threatened species occurring in protected areas and recommendations for their further protection. Schulz (1984) and IUCN/WWF (1984) provide recommendations for improved protection of turtles and control in their trade; these recommendations should be considered in conjunction with those for reefs and reef invertebrates. Recommendations for improvements in environmental law and legislation for reefs and reef-associated species are given in Salm (1984a) and Salm and Halim (1984b).

Recommendations for future reef research are given in Brown and Supriharyono (1985). Training of marine scientists is considered a high priority and efforts have already been made by Unesco (Brown, in press) and the Snellius II Expedition, which held training courses in Ambon and Ujung Pandang (Van der Land and Sukarno, 1986). Actions taken so far to train people in the management and planning of marine protected areas are described in Salm and Halim (1984c) and there is urgent need for further work in this field.

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# JAVA

## BALURAN PROPOSED NATIONAL PARK

**Geographical Location** North-east tip of Java; 7°50'S, 114°25'E.

**Area, Depth, Altitude** 25 000 ha are protected. A proposal has been made to extend the boundary 1 km seaward from the mean high-tide mark. Reefs extend from sea-level to 28 m depth. The highest peak in the park is 1247 m (UNDP/FAO, 1979b).

**Land Tenure** Government.

**Physical Features** The park is dominated in the centre by the extinct Baluran Volcano which has a crater wall of 900-1247 m in height, enclosing a caldera about 600 m deep. There is a broad lowland mantle 5-7 km wide on the north and east side of the volcano which borders the sea (IUCN, in prep.). The coastline of about 40 km consists of a variety of habitat types. Mud and mangroves are found in the lagoon at Bilik on the north coast where water visibility is less than 0.5 m. Other small mangrove areas, black (volcanic) and white (coral) sand beaches, and rocky outcrops are found along the rest of the coast. Coral reefs occur off shore from Gatal and Bilik in the north, in the region of Mesigit and Bamah in the east, and adjacent to Bajulmati in the south (UNDP/FAO, 1979b).

**Reef Structure and Corals** In general, coral reef communities are dominated by various species of *Acropora* and big heads of *Porites lutea*. In shallower water, *Millepora* spp. predominate with *Acropora*, while 5-6 m below low tide level *Seriatopora hystrix* and *Stylophora* become common. A full species list has not been compiled (UNDP/FAO, 1979b).

**Noteworthy Fauna and Flora** The shore of Baluran is an important ground for milkfish *Chanos chanos*. Large numbers of garden eels *Taenioconger* and sea snakes occur in some shallow water soft-bottom habitats. The reef fauna is considered to be representative of Indonesian reefs in general (UNDP/FAO, 1979b). The terrestrial fauna and flora is described in IUCN (in prep.).

**Scientific Importance and Research** No information.

**Economic Value and Social Benefits** Milkfish *Chanos chanos* are harvested as larvae and raised to marketable size in brackish-water fish ponds outside the park, near Surabaya. About 1000 people in Baluran are reported to earn their living by catching milkfish. Subsistence fishing for food and the collection of ornamental fish for the aquarium trade occur along much of the coastline. Shells are collected at low tide. Coral is removed from the reefs to supply the lime factories at Meneng, south of the Park. Baluran is reported to have good potential for marine tourism; there is a guesthouse at Bamah and SCUBA-diving tourists occasionally visit the area (UNDP/FAO, 1979b).

**Disturbance or Deficiencies** The major problem is removal of coral for the lime factories at Meneng. Two offshore reefs just north of the park boundary at Bajulmati have been stripped of corals and there are dangers that reefs elsewhere in the park will be exploited. Reef fish are collected for the ornamental fish trade but there are no reports of the impact and extent of this activity or of mollusc collecting (UNDP/FAO, 1979b).

Milkfish are heavily harvested but are reported to be very abundant around Baluran. The main problems arise from habitat damage caused by the fishermen dragging long straw brushes over the reef flat or digging channels perpendicular to the shore to concentrate the milkfish. The latter activity is particularly harmful because it speeds up erosion of the beach. Fishermen also cause disturbance on land by collecting firewood and building materials, and frightening wildlife (UNDP/FAO, 1979b).

**Legal Protection** According to Salm and Halim (1984c), Baluran was first declared as a Wildlife Reserve in 1962, including an area of coral reef. Subsequently declared a National Park 6.3.80 but legislation enabling the establishment of national parks is still lacking. Terrestrial fauna is fully protected (IUCN, in prep.). Fishermen require two licences to collect milkfish: one from the local branch of the Fishery Department in Banyuwangi and another from the PHPA (UNDP/FAO, 1979b).

**Management** The PHPA Section Office is at Jl. Jend. A. Yani 108, Banyuwangi, East Java. Park headquarters, staff quarters, visitor centre and nature trails have been established within the park. The park is zoned, with a buffer zone outside the reserve, development zones (visitor centre, nature trails, park headquarters, staff quarters) totalling less than 5% of the area, and a wilderness zone covering 95% in which only very minor developments are permitted (IUCN, in prep.).

**Recommendations** The coral reefs and other marine ecosystems would be valuable additions to the proposed National Park, and it is recommended that the boundary be extended 1 km seaward from the mean high-tide mark. This is considered a Fourth Order Priority. Coral extraction should be stopped immediately and collecting of milkfish phased out. PHPA should encourage continued research by the Fisheries Department (Fisheries Research Station in Jepara, Central Java) into artificial rearing of milkfish to avoid collecting them from the wild. It is recommended that all fishing activities should be prohibited within the marine extension (UNDP/FAO, 1979b; Salm and Halim 1984a and c).

It is suggested that the whole coastline and marine section be designated as a wilderness zone, with the exception of two small recreation zones. One of these would be directly outside the proposed visitor centre at Bamah; the other would incorporate the sandy beach at Bajulmati. It is proposed that the new guesthouse at Bamah should be converted into a marine visitor centre and that a small boat harbour be constructed here.
About five mooring buoys should be established on the Bamah reefs and another three at Labuhan Merak, to avoid disturbance of the garden eel community (UNDP/FAO, 1979b).

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## KARIMUNJAWA PROPOSED WILDLIFE RESERVE

**Geographical Location** About 120 km north of Semarang, central Java; 5°50'S, 110°20'E.

**Area, Depth, Altitude** 111 625 ha; average depth of surrounding waters 12-30 m.

**Land Tenure** No information.

**Physical Features** Karimunjawa Island is the largest of a group of 14 small islands with associated coral reefs. Surrounding waters are less than 50 m deep, and mainly have a sandy and muddy bottom. Silt content of these waters is high and visibility is no more than 10 m. The islands are exposed to monsoons in February and August. The former blows from the north-west and is the strongest (Foster-Smith, 1977).

**Reef Structure and Corals** Karimunjawa is surrounded by a fringing reef to a depth of 10-15 m with patch reefs in more sheltered areas. Foster-Smith (1977) provided brief descriptions of the reefs at three sites. *Porites nigrescens* was common in sheltered positions. Sya'rani (1986) provides information on per cent coral cover.

**Noteworthy Fauna and Flora** Giant clam species, including possibly a few *Tridacna gigas*, spiny lobsters, nesting seabirds, mangroves, nesting Green *Chelonia mydas* and Hawksbill *Eretmochelys imbricata* Turtles occur (Brown and Muskanofola, 1985; Salm and Halim, 1984; Usher, 1984).

**Scientific Importance and Research** The area has been visited by Newcastle University expeditions in 1977 and 1986. The Giant Clam fishery has been investigated (Brown and Muskanofola, 1985; Sya'rani, 1986).

**Economic Value and Social Benefits** Four of the islands are inhabited, fishing and the collection of fossil giant clam shells for the tile trade being important occupations. The latter is described by Brown and Muskanofola (1985), Edwards and Wirutalingga (1986) and Sya'rani (1986).

**Disturbance or Deficiencies** There was significant coral mortality in 1983 when the abnormal El Niño of that year caused seawater temperatures to rise as much as 5°C above normal (Brown and Supriharyono, 1985). There is heavy collecting pressure on reef invertebrates by local inhabitants and itinerant divers (Usher, 1984). Although populations of the smaller species of Giant Clam are still thriving the larger species are extremely rare, if not extinct. However, the collection of fossil *T. gigas* shells is not as damaging to the coral environment as has been reported elsewhere (Brown and Muskanofola, 1985).

**Legal Protection** None.

**Management** None.

**Recommendations** A proposal has been made to establish the Karimunjawa Islands and reefs as a wildlife reserve as a "First Order Priority" (Salm and Halim, 1984a and c). It is considered a high priority area for invertebrate conservation. If living *T. gigas* are found, a sanctuary zone should be established and an intensive public relations campaign must be launched to gain the support of local people (Usher, 1984). The potential for reintroduction of the larger species of Giant Clam and for the encouragement of mariculture or fishery development seems great and is strongly advocated (Brown and Muskanofola, 1985).

## KEPULAUAN SERIBU RESERVE, PROPOSED MARINE NATIONAL PARK AND ADACENT ISLANDS

**Geographical Location** Java Sea, north of Jakarta in West Java; 5°26'-5°37'S; 106°24'-106°37'E.

**Area, Depth, Altitude** The Reserve covers 10 800 ha (the area of the proposed Marine National Park and buffer zone). Reefs extend from sea-level to a maximum depth of 20 m. The cays are low-lying (up to 3 m above sea-level) and extend over a distance of 80 km, with several more widely spaced islets and reefs extending a further 32 km.

**Land Tenure** At least 23 of the islands are privately owned, having been sold to developers and private individuals after the proposals for the park were submitted in 1979. The remaining area is Government-owned (IUCN, in prep.).

**Physical Features** The islands and reefs of the Seribu Archipelago lie on a substrate of mud and sand typical of the Sunda Shelf. There are about 110 islands and many submerged and emergent patch reefs. All the islands are coral cays and are formed of coral debris and other erosional products of the reef which are flung up by waves onto the reef flat. The cays are usually small (less than 10 ha on average) and are surrounded by a narrow white beach of finely ground coral sand (UNDP/FAO, 1982b). Pulau Bokor and Pulau Rambut lie to the south of the proposed Marine National Park area and are small reef-fringed, vegetated islands (Salm and Halim, 1984c). An early description of the geomorphology is given in Zaneveld and Verstappen (1952). Hydrology of Jakarta Bay is described in Horikoshi and Soegiarto (1984). Ongkosongo and Sukarno (in press) provide a comprehensive overview of the area and work carried out there.

The islands are influenced by two major weather patterns. The north-west monsoon season from November to March is characterized by short periods of strong winds, violent squalls and heavy rain. During this period there is an easterly following current through the islands, the seas are rough and water clarity decreases. The south-east monsoon season from April to October is calmer, currents are westerly flowing and there is a general increase in water clarity (Brown *et al.*, 1983; UNDP/FAO, 1982b).

**Reef Structure and Corals** A total of 132 species from 68 coral genera and subgenera have been identified in the park and are listed in UNDP/FAO (1982b). More recently, 193 species in 56 genera have been recorded in the islands in the course of a Unesco workshop (Moll and Suharsono, in press). At least two principal types of patch reefs are distinguishable: those that are permanently submerged and those at sea level which may emerge at low tide. Both types offer a variety of habitats, each with characteristic coral morphologies and specific biotic assemblages (Salm *et al.*, 1982a and b).

The reef flat of permanently submerged patch reefs is dominated by branching and occasional massive corals, especially *Acropora* and *Porites*. The reef slope has mainly massive corals such as *Mycedium*, *Echinophyllia*, *Oxypora* and *Pachyseris* (Salm *et al.*, 1982a).

The inner reef flat of sea-level patch reefs in sheltered habitats is characterized by sand, coral debris and small branching or massive corals such as *Acropora, Porites andrewsi* and *P. lutea*. On the outer reef flat branching corals and massive types form micro-atolls and *Acropora, Porites andrewsi* and *Porites cf lutea* are typical (Salm *et al.*, 1982a). Brown *et al.* (1983) studied the coral assemblages of reef flats around Pulau Pari to the south of the park boundary and found that all sites were dominated by *Acropora* spp., which showed a distinct zonation pattern. *A. pulchra/aspera* dominated the unconsolidated landward section of the outer reef flat, *A. digitifera* occupied the mid-seaward section, while *A. hyacinthus* colonized the seaward edge. Salm *et al.* (1982a) report that the reef crest is dominated by branching, tabular, massive and foliaceous corals such as *Acropora* spp., *Clavarina, Pavona cactus, Pachyseris, Montipora foliosa, Echinopora lamellosa* and *Galaxea*. The upper fore reef slope is typified by branching and vase-shaped colonies, including *Acropora, Pachyseris, Turbinaria*, and *Echinopora lamellosa*. On the lower slope massive forms, such as *Mycedium, Echinopora, Oxypora*, and *Pachyseris*, are predominant.

The inner reef flat of sea-level patch reefs in exposed habitats is similar to those in sheltered habitats. On the outer reef flat the dominant forms are robust, branching, small, tabular and massive corals, such as *Acropora* spp., *Porites cf lutea* and faviids (Salm *et al.*, 1982a). *Acropora* spp. show a distinct zonation pattern similar to that for sheltered habitats. Species diversity is lower on exposed reef flats than in sheltered areas (Brown *et al.*, 1983). The reef crest is typified by tabular and large and small massive corals, such as *Acropora, Porites cf lutea* and *Coeloseris*. The upper fore-reef slope supports a mixed coral assemblage while the lower slope is dominated by massive types such as *Mycedium, Echinophyllia, Oxypora* and *Pachyseris* (Salm *et al.*, 1982a).

Numerous studies have been carried out on reefs outside the Reserve area. The distribution of red algae on the reef at Pulau Pari is described by Atmadja (1977). Gooding (1969) surveyed the reefs of Pulau Pari, and reported the best reef development to be in the lagoons of Goba Soa Besar and Goba Buntu. Brown *et al.* (1983) and Sya'rani (1983) also studied shallow reefs at Pulau Pari. Greater coral diversity was found in the relatively sheltered southern reefs (74 species recorded) and reduced diversity on the more physically exposed northern reefs (43 species recorded). Sukarno (1977) described corals around Air Island, to the south. White (1986) has also surveyed some of the reefs. Early descriptions of the reefs and islands include Umbgrove (1929b, c and 1939b) and Verwey (1929, 1931a and b).

**Noteworthy Fauna and Flora** Hawksbill *Eretmochelys imbricata* and a few Green *Chelonia mydas* Turtles nest and feed around the islands. Pearl oysters, commercial trochus, cowries and turban shells occur in the area but stocks are seriously depleted (Salm *et al.*, 1982a; Usher, 1984). Fish in seagrass beds are described by Hutomo and Martosewojo (1977) and on fringing reefs by Hutomo and Adrim (in press). An early description of the flora of the islands is given in Zaneveld and Verstappen (1952). Pulau Rambut, to the south, is important for seabirds (Salm and Halim, 1984c).

**Scientific Importance and Research** Apart from the UNDP/FAO (1982b) study, there has been little research conducted within the park itself. However, extensive work has been carried out on the reefs around Pulau Pari, south of the buffer zone boundary, where the National Insitute of Oceanology (LON) operates a research station (e.g. Brown *et al.*, 1981; Brown *et al.*, 1983; Brown *et al.*, 1985). The area was used for a Unesco reef research workshop (Brown, in press) which resulted in the formation of a database designed to monitor environmental trends in the area (Harger, in press).

**Economic Value and Social Benefits** The reefs are indispensable to local fishermen. Small (279) and medium-sized (85) fishing boats, including muro-ami boats, are based in the buffer zone south of the park boundary (Subani, 1978). Food fish and ornamental fish for the aquarium trade are collected. Molluscs are harvested for food and for sale as curios or for other commercial purposes. Turtle eggs, hatchlings and adults are collected and eaten, sold for rearing on Pulau Tidung, or stuffed for the curio trade. The reefs have been an important source of limestone, although mining is illegal (Salm *et al.*, 1982a).

The Seribu Archipelago is situated within easy reach of Jakarta (20 minutes by air, 1-6 hours by boat) and offers its residents many opportunities for recreation and relaxation. The park has enormous potential for the development of water sports (notably snorkelling, SCUBA diving and sailing) and beach-related activities. PT Pulau Seribu Paradise currently own or lease 12 islands and are negotiating the lease of six others, all of which will be developed for tourism which is becoming a major industry. There is also considerable opportunity for education and research (Salm *et al.*, 1982a). There is a commercial diving operation at Pulau Putri and divers are taken to the reefs by villagers from Pulau Kelapa (Kvalvagnaes *et al.*, 1982); the Indonesian SCUBA Diving association runs a diving operation at Pulau Kotak Kecil (Salm, 1981).

**Disturbance or Deficiencies** *Acanthaster planci* was studied at Pulau Tikus (Aziz and Sukarno, 1977) but there have been no reports of major infestations. In 1983, many reefs in the archipelago were affected by the abnormal El Niño. Seawater temperatures rose 5°C above normal for about a month. Pulau Pari, Pulau Tikus and islands in the south-west were very badly affected, particularly the reefs off the southern shores. On Pulau Tikus, for example, living coral coverage fell from 20-40% to less than 5%. However, there has been almost 50% recovery in the three years since the damage occurred, although the reefs now have a different composition with massive species being more abundant than branching species (Brown, in press; Brown *et al.*, in press; Brown and Supriharyono, 1985; Suharsono, 1984).

Fisheries activities have caused considerable disturbance and degradation within the park. Reef fish are plentiful in some areas but depleted in others. Valuable commercial species (notably groupers, snappers and porgies) are uncommon and small, or entirely absent on heavily fished reefs. Shallow and deep coral colonies are smashed during muro-ami and other reef-based fisheries which involve anchoring, walking and poling of boats over the reefs. Dynamiting has damaged reefs and takes place particularly in the northern, remote islands such as Pulau Dua and Pulau Pancalirang. Valuable species such as the Giant Clam *Tridacna gigas* are apparently extinct throughout the islands. In recent years the reef flats have been dug up to find the shells of dead clams buried there. Other molluscs, such as pearl oysters, commercial trochus, cowries and turbans, are harvested by free divers and their stocks have been seriously depleted (Subani, 1978; Salm, 1981; Salm *et al.*, 1982a; Usher, 1984). Corals are broken by commercial mollusc collectors and by snorkellers and SCUBA divers. Turtles and turtle eggs, particularly Hawksbills, have been heavily exploited, despite their endangered status (Salm, 1981; UNDP/FAO, 1982b).

On all but the smallest cays the original vegetation has been stripped away and replaced by coconut plantations or bungalows (Salm *et al.*, 1982a). Natural beach dynamics have been interrupted by the construction of solid piers, seawalls and boat-docking facilities by developers and private citizens. These have been built across reefs using coral mined illegally from the reef flat. Sections of reef have been destroyed, fine sediments released and water quality degraded by dredging operations and the digging of boat channels (Salm, 1981; Sya'rani and Willoughby, 1985; UNDP/FAO, 1982b). The reefs at Pulau Rambut were largely dead and smothered by sediments in 1981, mainly due to dredging for sand for beaches at Ancol. The reefs became progressively better around the more remote islands, such as Pulau Karya. Reefs around the latter are probably good because the island is the home of the Camat (chief) whose presence may deter dynamiters and coral miners (Salm, 1981). In 1986, a tourism development project was started on three islands in the proposed wilderness zone which poses further threats to the area; the park has now been added to the IUCN/CNPPA list of "most threatened protected areas".

The area is at considerable risk from pollution, which could kill reef communities or reduce the value of beaches for recreation. Potential pollution includes oil discharges and rubbish from ships approaching the harbour at Jakarta, northward expansion of pollution from Jakarta Bay (*see* Introduction) and increased runoff of sediments from the land causing increased turbidity of ocean waters. Moll and Suharsono (in press) found that reef degradation decreased from the Bay of Jakarta outwards through the Seribu archipelago and related this to diminishing human impact and pollution. There is also the possibility of damage from discharge of drilling muds and cuttings from oil-drilling sites located just west of the park (Salm *et al.*, 1982a; Soegiarto and Polunin, 1982). Oil residues are now visible along the strandline on beaches in the north of the archipelago (Brown, in press).

**Legal Protection** Kepulauan Seribu was declared a Reserve on 21.7.82 under Ministerial Decree No. 527/KPTS/UM/7. This is an interim measure until legislation is established to facilitate its reclassification as a marine national park (Salm *et al.*, 1982a and b). Coral mining in the islands is controlled by Decrees of 1.12.70 and 6.11.70.

**Management** The Chief Warden (Kepala Sub-Balai) is responsible for overall administration, and the reserve headquarters is on Pulau Panjang.

**Recommendations** The management plan (UNDP/FAO, 1982b) includes detailed recommendations and stresses that certain immediate actions should be taken. Land use should be zoned and controlled to encourage development of camping grounds and other types of low-intensity use. Regulations prohibiting coral mining and the use of coral for any form of construction should be enforced, and there should be a moratorium on the construction of piers, docks, harbours and seawalls on the island. All dredging operations on or near reefs and construction over reefs should be halted. Continued collection of turtle eggs, hatchlings and adults must be prohibited and all turtles currently held in tanks or ponds in the islands north of Pulau Kelapa should be released under PHPA supervision.

Pulau Pari and the entire reef system on which it lies should be declared a research zone under the sole jurisdiction of the National Institute of Oceanology (LON) or Lembaga Limu Pengetahuan Indonesia (LIPI) for the purposes of marine biological/ecological/oceanographic research, and monitoring of the encroachment of Jakarta Bay pollution, in order to alert authorities to potential pollution problems in the marine park.

The UNDP/FAO Management Plan proposes that a zoning scheme is implemented for the park, and includes detailed maps and descriptions of the zones. Commercial fishing, using hook and line, cast net, small seine and approved muro-ami will be confined to a buffer zone surrounding the park. Within this, recreational fishing, using a line with no more than two hooks, will be permitted except in designated areas. All traditional and established uses, other than those which are damaging to the environment, incompatible with park objectives or already restricted by regulations, will also be permitted (Salm, 1985; Salm *et al.*, 1982a and b; UNDP/FAO, 1982b).

Within the proposed Park, areas of particular conservation interest would be designated for sanctuary status, equivalent to strict nature reserves. Two Hawksbill Turtle Sanctuaries (around Pulau Gosong Rengat in the north-west and the Pancalirang islands in the north-east) and a Coral Sanctuary (north of Pulau Bira Besar in the centre of the park) have been proposed. These areas would be closed except to PHPA staff and accompanying scientists (Salm *et al.*, 1982a and b; Salm, 1985; UNDP/FAO, 1982b). Usher (1984) considers the area to be a high priority for reef invertebrate conservation.

An intensive use zone is proposed for the central region of the park, around Pulau Panjang where tourist facilities would be developed under PHPA control. Within this area, recreation zones would be established, where different activities, such as snorkelling, SCUBA diving, recreational fishing, picnicking, beach-based activities and boating, could be pursued without conflict or environmental damage. Buoys should be established at the snorkelling and SCUBA diving sites (Salm, 1985; Salm *et al.*, 1982a).

It is recommended that an area surrounding the proposed sanctuaries and intensive use zone be designated a wilderness zone for low intensity use. Removal or harvesting of any marine or island product would be prohibited, and the area would enable the marine park to be appreciated in its natural setting (Salm *et al.*, 1982a). Additional, specific, regulations are required to control activities within the proposed National Park and its constituent zones (UNDP/FAO, 1982b). A project concept for the management of the area is currently being prepared by IUCN (McNeely *et al.*, 1986).

Pulau Bokor and Pulau Rambut, lying to the south of the proposed Marine National Park area, were created wildlife reserves in 1921 and 1939 respectively. Salm and Halim (1984a and c) recommended that a marine extension be declared to the reserves in order to protect the reefs; this is considered a Third Order Priority.

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## PENANJUNG PANGANDARAN NATURE RESERVE

**Geographical Location** South coast of West Java close to the border with Central Java; 7°43'S, 108°39'E.

**Area, Depth, Altitude** The size of the existing reserve is 530 ha. A proposal has been made that the reserve boundary should be extended 500 m out into the sea, in order to incorporate the coral reefs which are reported to extend from sea-level to a depth of 2-3 m (Kvalvagnaes and Halim, 1979b). The highest point on the Pangandaran peninsula is 148 m.

**Physical Features** The Penanjung Pangandaran Reserve is situated on the Pangandaran peninsula, which is connected to the mainland by an isthmus 200 m wide. From the isthmus the terrain on the peninsula is at first relatively flat before it rises gradually towards the south as a high plateau. The southern side of the plateau drops off at an average height of about 75 m into the sea. The coastline here consists of steep volcanic cliffs and rocks and, unless the sea is completely calm, is practically inaccessible. Underwater, the steep rocky slope continues, and depths of 20-40 m are reached within 100 m of the southern shore. There are only isolated coral colonies here, typical of such rough waters (Kvalvagnaes and Halim, 1979b). The best coral reefs fringe the north-west coast of the peninsula; there are also fringing reefs along the north-east-facing coast. On either side of the isthmus the water is extremely shallow and there is sufficient shelter for a safe anchorage.

**Reef Structure and Corals** The survey report (Kvalvagnaes and Halim, 1979b) only describes the reef off the north-east coast, between Tg. Batumandi and Tg. Sodonglandalk. The reef flat is relatively barren, but with some corals, notably *Favia* and *Favites*, in crevices and tide-pools. From the reef flat the corals continue down to a depth of 2-3 m where there is a sandflat. *Acropora cf symmetrica* is dominant, with an estimated 50% cover. *Millepora incrustans* is also common, with an estimated 30% cover, and the remaining 20% is made up of *Acropora* spp., *Agaricia* sp., *Pocillopora* sp. and some other genera.

**Noteworthy Fauna and Flora** Terrestrial fauna and flora are described in IUCN (in prep.). Details of noteworthy marine flora and fauna are not included in the survey report.

**Scientific Importance and Research** No information.

**Economic Value and Social Benefits** Fishing is apparently an extremely important occupation for the people of Pangandaran, employing about 400 people full time. They catch fish for food, and supply the souvenir shops with corals, shells, starfish and fish suitable for mounting and making into curios (Kvalvagnaes and Halim, 1979b). The nature reserve is one of the most popular in Java, attracting week-end trippers from Bandung, 223 km away, and tourists on their way to or from Bali (Anon., 1984). In 1978 nearly 150 000 people visited the reserve. At present, only a few of the visitors snorkel over the reefs but walking over the reef flats at low tide is a popular activity.

**Disturbance or Deficiencies** On the north-eastern coast of the reserve the corals are seriously affected by silt brought down by the Cikideng River and by pollution from the village and fishing harbour. Most of the corals close to the shore near the guesthouses are already dead. The reef flat has been seriously affected by people trampling over it and collecting corals and shells. Commercial exploitation of reef fauna is considerable, and is said to be adversely affecting the reefs (Kvalvagnaes and Halim, 1979b). On land, an unplanned recreation park with food, drink and souvenir stalls has developed near the entrance to the reserve.

**Legal Protection** The coral reefs and other marine areas to the seaward side of the high tide mark are legally unprotected, but the area between high and low tide is maintained as if part of the reserve established in 1934. Visitors are prohibited from walking on the reef (Kvalvagnaes and Halim, 1979b). The recreation park was defined in 1978.

**Management** An information centre has been built just inside the reserve, but interpretive material has not been provided. Wardens are present in the area but regulations are not enforced (Kvalvagnaes and Halim, 1979b).

**Recommendations** Kvalvagnaes and Halim (1979b) and Salm and Halim (1984a and c) suggest that the boundary of the reserve should be extended 500 m out from the low-tide mark, that walking patches should be provided on the reef flats in order to avoid too much environmental damage, and that all collection of shells, fish, coral and other marine life should be prohibited. It is also recommended that an aquarium be built to interest and educate visitors. The seaward extension of the reserve is considered a fourth order priority.

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## UJUNG KULON PROPOSED NATIONAL PARK

**Geographical Location** Western tip of Java, including the islands lying in the Sunda Strait, between Java and Sumatra; 6°45'S, 105°20'E.

**Area, Depth, Altitude** There are three separate elements: Ujung Kulon and Pulau Peucang 7500 ha; Pulau Panaitan 4000 ha; Krakatau 3140 ha; estimates of the total area are variable, but 76 100 ha is considered approximately correct (IUCN, in prep.). Reefs extend from sea-level to depths of about 25 m (Halim and Kvalvagnaes, 1980). Ujung Kulon rises to a maximum altitude of 480 m, and on Pulau Panaitan the hills rise to 320 m (IUCN, in prep.).

**Land Tenure** Government-owned.

**Physical Features** Ujung Kulon is a triangular peninsula joined to the mainland by a low-lying isthmus 1-2 km wide. The southern coastline is exposed to high winds and heavy wave-action. It consists of long, white, sandy beaches broken by a few rocky heads, but is too sandy and exposed for any extensive coral development. The western coastline is also exposed, but to the north is a protected bay fringed by mangroves, and with some coral growth. The best reef development is seen on more open parts of the north coast. These areas face some storms during the north-west monsoon period but are generally less exposed to wave action than the west and south coasts.

The islands are similarly affected by heavy seas, and fringing reefs are best developed in the more sheltered situations. Pulau Peucang is a small, raised coral island but Pulau Panaitan and the Krakatau Islands have firm rocky bases which provide a good base for coral growth. Fringing reefs are the commonest type of reef in the area, but there are also some small patch reefs (Salm *et al.*, 1982d).

**Reef Structure and Corals** Salm *et al.* (1982d) found that the reefs around Ujung Kulon and Pulau Panaitan were dominated by a few common species, which comprised about 90% of the total coral mass. By far the most common coral was the tabletop coral *Acropora* cf. *symmetrica*, which in some areas (between 3 and 15 m) dominated the community completely (Halim and Kvalvagnaes, 1980). In shallow water, bushy *Acropora* spp. and *Pocillopora* spp., both rugged forms capable of withstanding heavy wave-action, were dominant. *Millepora platyphylla* and the massive *Porites lutea* were also found all the way up to the surface. Below 2-3 m depth bushy *Acropora* spp. were replaced by tabletop *Acropora*, and *Millepora platyphylla* by *M. dichotoma*. Below 15 m hermatypic corals became relatively scarce.

A total of 122 species of hard coral was recorded from the Krakatau reefs. It was suggested that this high diversity (especially of genera) could be due to disturbance relating to volcanic activity and/or to the lack of overcrowding of corals, which lead to solitary or inconspicuous corals being easily spotted (Salm *et al.*, 1982d). Generic diversity was highest in areas of unstable rockfall below cliffs. It was also high on shallow patch and fringing reefs with mixed coral assemblages, but lower on shallow reef habitats dominated by *Acropora*.

Some of the patch reefs at Krakatau were clearly in the process of expansion. Talus was accumulating around the base of large *Porites* boulders and between the boulders and the reef, and being colonized by secondary pioneers such as *Acropora, Pocillopora* and alcyonarians.

**Noteworthy Fauna and Flora** All five species of marine turtle occurring in Indonesia are found around Ujung Kulon and Krakatau, and both the Green Turtle *Chelonia mydas* and the Hawksbill *Eretmochelys imbricata* nest on the beaches. Monitor Lizards *Varanus salvator* are common along the coastline, and the Saltwater Crocodile *Crocodylus porosus* is also present.

The fish life is rich, and many big specimens of barracuda, sailfish, tuna, skipjacks and sharks are seen in the waters around Ujung Kulon. Coral reef fish communities are also noticeably diverse. Large numbers of spiny rock lobsters and crabs occur in the Ujung Kulon area, and the reefs, mudflats and sandy and rocky coast all provide suitable habitats for molluscs. The preliminary list includes many species of value as food or curios e.g. *Strombus* spp., *Cypraea* spp., *Conus* spp. and *Lambis* spp. Large specimens of *Tridacna squamosa* occur on the Krakatau reefs (Salm *et al.*, 1982d). Terrestrial flora and fauna are described in IUCN (in prep.), the park being particularly important for the Javan Rhino *Rhinoceros sondaicus* and a variety of endangered terrestrial birds.

**Scientific Importance and Research** The preliminary survey of the reefs and marine areas around Ujung Kulon and Pulau Panaitan reveals that they are important primarily because they are relatively undisturbed, and support an exceptionally rich fish life (Halim and Kvalvagnaes, 1980). The overwhelming value of the Krakatau reefs lies in their potential for research on reef colonisation and development (Salm *et al.*, 1982d). Reefs with such precise dates of origin are rare. There is a research station on Pulau Peucang, but no special facilities are available.

**Economic Value and Social Benefits** Fishing boats visit the area when sea conditions allow, mostly in search of deep water and oceanic species, rather than reef fish. Red algae are collected from the intertidal zone at the reserve boundary on the south coast, and are used in the production of agar-agar. Mollusc and fish resources are considered to be rich, but at present are underexploited. The National Park has potential for tourism and recreation, although in 1980 only about 500 people a year were visiting it (Halim and Kvalvagnaes, 1980).

**Disturbance or Deficiencies** Land clearance for agriculture on the Ujung Kulon peninsula has led to sedimentation and death of corals in the sheltered bay on the north-east coast (Halim and Kvalvagnaes, 1980). On the Krakatau Islands trees are being cut for timber and firewood, and areas cleared for campsites (Salm *et al.*, 1982d) which would lead to increased siltation and damage to these reefs. Dynamite fishing is reported to occur on the Krakatau reefs and fishermen have also caused damage by anchoring or poling their boats over the coral (Salm *et al.*, 1982d). Turtle eggs are collected by fishermen, and there is also considerable predation on the nests by pigs and Monitor Lizards (Halim and Kvalvagnaes, 1980).

**Legal Protection** Declared as a National Park 6.6.80 but legislation specifically designed for establishing national parks is still lacking. The marine areas are incorporated in the proposed National Park. The terrestrial flora and fauna are fully protected through the Strict Nature Reserves declared at Krakatau in 1917, Pulau Peucang-Panaitan in 1937 and Ujung Kulon in 1958 (Salm and Halim, 1984c). Collection of corals, live shells and other marine animals is prohibited. Krakatau was declared as part of the National Park in 1983 (IUCN, in prep.).

**Management** The Park headquarters are on the Ujung Kulon peninsula, at Taman Jaya. The PHPA regional office is in Labuan (Jl. Caringin 2, Labuan, Benten, W. Java).

**Recommendations** A zoning scheme for Ujung Kulon/Pulau Peucang and for Pulau Panaitan was proposed in 1980. On Pulau Peucang a sanctuary zone was proposed for research only, while two sanctuary zones on the west and south coasts of the peninsula are to protect turtle nesting beaches. Only guided trips for tourists are allowed. A considerable part of the protected area is proposed as a wilderness zone, where visitors are allowed to snorkel and SCUBA dive. Three extensive use zones are intended as recreational areas (swimming, surfing etc., but not water skiing) (Halim and Kvalvagnaes, 1980). It is not known whether the zoning has been implemented. The zoning of the marine areas is separate from that of terrestrial areas.

For Krakatau, Salm *et al.* (1982d) recommended that certain areas should be declared off-limits to tourists and reserved exclusively for scientific research. Fishermen should be prevented from approaching the islands and reefs. It was proposed that the headquarters for the Krakatau Islands should be on Sabesi Island, beyond the National Park boundaries to the north, and that a ranger station should be established on one of the Krakatau Islands. Marine extensions have been recommended for the reserves at Krakatau, Pulau Peucang-Pulau Panaitan and Ujung Kulon as a first order priority (Salm and Halim, 1984a and c). It is anticipated that these will help to prevent the few damaging activities that occurred in the past.

# NUSA TENGGARA

### BALI BARAT PROPOSED NATIONAL PARK

**Geographical Location** North-west corner of Bali; 8°10'S, 114°25'E.

**Area, Depth, Altitude** Total area 77 348.5 ha; comprising 19 558.8 ha Bali Barat Wildlife Reserve, 6220 ha of coral reefs and marine waters, and 57 569.7 ha of primary montane Protection Forest (IUCN, in prep.). The reefs extend from sea-level to a maximum depth of 28 m (lower limit of "abundant coral") (Halim *et al.*, 1980). Pulau Menjangan (Deer Island) is a low-lying island with an altitude of a few metres, but several peaks over 500 m occur on the peninsula and, further inland, Gunung Merbak rises to 1386 m (IUCN, in prep.).

**Land Tenure** Government-owned.

**Physical Features** The western part of the mainland consists of a peninsula of uplifted coral limestone no higher than 310 m and includes Pulau Menjangan. Further inland, within the park, are rugged volcanic mountains (Anon., n.d.).

A fast south-bound current flows through the Bali Strait into the Indian Ocean, and its influence is felt in the north-eastern parts of the National Park. A strong current develops regularly along the north coast of Pulau Menjangan, and in the strait between the island and the mainland. The northern coastlines are the most exposed to wave action but, in general, conditions are calm. Water temperature falls to approximately 25.5°C in August and increases to as much as 28.5°C in December (Polunin *et al.*, 1980). The wet season is from December to March with drier more stable weather from April to November. Seasonal streams form during the wet season when rainfall may reach 1500-2000 mm.

Coral reefs are of the fringing type, and show varying degrees of development around the Park. They are virtually absent from the south-western coast in the Bali Strait below Gilimanuk, an area which is characterized by shifting coastal sands of volcanic origin and strong currents close to the shore. Reefs are poorly developed within the shallow mangrove-lined bays on the mainland, where water clarity is reduced. The best developed reefs are around Pulau Menjangan. On the south-east side of the island the reef is steep, while on the north-facing coast the upper reef is more rounded and there are shallow surge-channels on the outer reef flat (Polunin *et al.*, 1980). Further information is given in Polunin *et al.* (1983).

**Reef Structure and Corals** There is considerable variation in reef quality within the National Park. For example, the reefs around Pulau Menjangan are rich in species and structure, while those in many of the near-shore areas, such as at the mouth of Teluk Lumpur, in Teluk Terima and in Teluk Banyuwedang, are relatively poor. These variations can be related to the clarity of the water, water movement and other factors having an important influence on reef communities (Halim *et al.*, 1980).

Simple line transects have been made at several sites within the Park, and these give basic comparative information. At the survey site on the north coast of Pulau Menjangan, the reef drops steeply into deeper water, after an extensive reef flat, about 200 m wide. The outer rim of the reef flat is covered with corals, mainly *Millepora* and different species of *Acropora*. Bush and table *Acropora* are particularly common. Bush *Acropora* continues down to about 6 m, while table *Acropora* goes nearly all the way down to 25 m, where hermatypic corals stop and gorgonians take their place. Gorgonians were found from 11 m, but did not become common before 15 m. Other soft corals were rare. Amongst the other hard corals recorded were *Favia, Favites, Echinopora, Merulina*, and big heads of *Porites lutea* (UNDP/FAO, 1979a). A total of 35 species were recorded from this site (Polunin *et al.*, 1980).

On the north coast of the mainland peninsula, corals continue down to 18 m. Near the surface different species of *Acropora* dominate, but *Millepora, Merulina, Favia* and *Favites* are also found. Below 6 m, the most abundant species are *A. cervicornis* and *Seriatopora hystrix*. Other species of *Acropora*, such as the table coral *A. symmetrica*, are also common, and various other species can be found, but in smaller numbers (UNDP/FAO, 1979a). A total of 29 species were recorded from this site (Polunin *et al.*, 1980).

Within the bay (Teluk Terima) on the north coast of the mainland, the reef flat extends seawards for more than 300 m before dropping gently down to 15 m. Here the corals stop on a muddy bottom. The central part of the reef flat is covered with seagrass, and the outer part by corals, mainly bush and table *Acropora*. In general the coral community is poorer than at the other survey sites. Species recorded include *Millepora alcicornis*, *A. echinata*, *Merulina ampliata*, *Seriatopora hystrix*, *P. lutea* and *Echinopora lamellosa*.

**Noteworthy Fauna and Flora** Porpoises are commonly seen, especially to the north of Pulau Menjangan. Hawksbill Turtles *Eretmochelys imbricata* were observed only along the northern coast of Pulau Menjangan (Polunin *et al.*, 1980). Sharks, the common White-tip *Triaenodon obesus* and the Black-tip *Carcharhinus* sp. were recorded from the north coast of both Pulau Menjangan, and the mainland peninsula. A single Whale Shark *Rhincodon typus* was seen in the Bali Strait (Halim *et al.*, 1980). The diversity of coral reef fish is high, especially around Pulau Menjangan (Halim *et al.*, 1980). Terrestrial flora and fauna is described in IUCN (in prep.).

**Scientific Importance and Research** The Bali Barat reefs, especially those around Pulau Menjangan, have been studied by Halim *et al.* (1980) and White (1986).

**Economic Value and Social Benefits** In 1980 there were reported to be about 3000 people living within the boundaries of the park, but it was emphasized that these residents did not extensively exploit the marine resources of the area. At this time, about 150 fishermen regularly entered the reserve or coastal waters as part of their principal economic activities. With the exception of ornamental fish collection and milkfish fishing, the fisheries are on a small scale, being either for subsistence or for local sale. Ornamental fish are caught by collectors based in the area of Bangsril in East Java. Over 70 species of reef fish are exploited but these may not now be collected within the boundary. Milkfish fry are caught during October/November and April/May and are sold for rearing in brackish-water fish ponds. Some of these ponds have recently been constructed east of Banyuwedang, outside the proposed National Park, on the north coast of Bali (UNDP/FAO, 1980).

Reefs in the area have been mined for limestone, but this activity has become less important in recent years. Those engaged in mining cross from east Java (Polunin *et al.*, 1980). Tourism is developing gradually, and Bali Barat is expected to become an important tourist attraction (UNDP/FAO, 1980). Accommodation is available nearby, the park is easily accessible by public transport and there are basic facilities for SCUBA diving.

**Disturbance or Deficiencies** Subsistence fisheries do not apparently have any detrimental effects on the coral reefs, except when explosives are used. Small craters have been found in rubble areas, for example in the strait at the western end of Pulau Menjangan. Ornamental fish collectors are highly selective in the species they take, and it is reported that species of anemonefish, butterflyfish and angelfish have been depleted (Polunin *et al.*, 1980). Incidental habitat damage has been caused by collectors using sodium cyanide or breaking corals (UNDP/FAO, 1980).

Mining of reefs for limestone has probably had the most serious impact in the area, but active patrolling by park staff has greatly reduced this activity since 1978. By 1980 it was confined largely to the western part of the park, the Bali Strait, and western end of the northern coast of Prapat Agung. Three boats were crossing from east Java to these areas, every boat carrying away with it some 100 cu. m of coral (Polunin *et al.*, 1980).

Domestic and industrial rubbish, particularly plastic bags, are a threat to the aesthetic value of the area. In February 1980 there was a large influx of rubbish into the park following heavy rains in east Java (Polunin *et al.*, 1980). Uncontrolled cutting of mangroves for wood and charcoal production has occurred in the area, especially in Teluk Terima. This could have a secondary effect on the health of neighbouring reefs, but apparently has been curtailed since 1978 by active patrolling of the park (UNDP/FAO, 1980).

**Legal Protection** Originally created a Protection Forest, converted to a Wildlife Reserve on 9.8.47 (Decree no. 4071); Pulau Menjangan (Deer Island) was added in 1978. Declared a National Park in October 1982 but legislation enabling the establishment of national parks is still lacking. The fauna is fully protected. Spearfishing in any form is prohibited and traditional fishing is allowed only in certain areas. Aquarium fish may not be taken and collection of coral, shells, or other invertebrates (alive or dead) is prohibited (Anon. n.d.).

**Management** Local administration is through the Chief Ranger/ Superintendent, Jl. Suwung, P.O. Box 320, Denpasar. Permits to enter the park can be obtained from the PHPA in Gilimanuk, Denpasar, or in Bogor (West Java) (IUCN, in prep.). There is a staff of fourteen. Existing headquarters and a field station are at Teluk Terima.

**Recommendations** The 1980 management plan (UNDP/FAO, 1980) recommends the establishment of specific zones. An area off the north-east coast of Teluk Terima is recommended as a sanctuary zone, where no person except PHPA staff on official business should be allowed entry except by written permission. This includes fringing reef backed by a sandy beach. The reefs elsewhere in Teluk Terima and around Pulau Menjangan would be within a wilderness zone, where people should be allowed entry provided they obtain an entry permit, and agree to abide by the regulations. Fishing or disturbance of any kind is prohibited within this zone; registered fishermen may pass through it but would not be allowed to fish, stop on the shoreline or anchor. Outside the sanctuary and wilderness zones is a proposed marine buffer zone in which registered, resident fishermen may fish using traditional methods or methods deemed by the National Park Superintendent as non-harmful to the protected marine systems and biota. Persons not registered as fishermen but who are visiting the park as temporary recreational visitors would also be able to fish in this zone using specified methods, providing the fish taken are not sold or otherwise commercially used. Salm and Halim (1984a and c) recommend an additional marine extension to the park as a first order priority.

It is also recommended that the marine protected area should be divided into an East and West District for administration and protection, the West District Office to be established at Gilimanuk and the East District Office at Labuan Lalang. Interpretive facilities would be included at both these offices. A visitor centre and headquarters could be located at Cekik (UNDP/FAO, 1980). It is recommended that snorkelling and SCUBA diving areas be identified on the reefs around Pulau

Menjangan, and anchor buoys installed. It is suggested that an increase in the number of buoys could be made after a few years, following an analysis of the impacts around the first buoys. Plasticized identification cards for fish and corals should be made available, and guides on tourist boats should receive some instruction in simple natural history interpretation.

Detailed monitoring and survey work on the coral reefs and mangroves should be continued so that visitor-related damage and other changes can be assessed. This would include studies of the effects of prohibiting collection of ornamental fish and the fry of milkfish (UNDP/FAO, 1980). It is recommended that the National Institute of Oceanology (LON), based in Jakarta, and the National Institute of Geology and Mining (LGPN), with headquarters in Bandung, Java, should be encouraged to participate in such surveys. There is also an excellent opportunity for the Environmental Study Centre (PSL) at Universitas Udayana in Denpasar, Bali, to become involved in long-term studies (UNDP/FAO, 1980).

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## KOMODO BIOSPHERE RESERVE AND PROPOSED NATIONAL PARK

**Geographical Location** About 30 km off the west coast of Flores in the Sape Straits between Flores and Sumbawa; 8°24'-8°50'S, 119°21-119°49'E.

**Area, Depth, Altitude** 70 000-72 000 ha, including 10 000 -12 000 ha marine waters; depth is 15-20 m; highest peak is Gunung Satalibo at 735 m (Unesco, 1986). Biosphere Reserve is on Komodo Island and comprises 30 000 ha. The Park includes Komodo Island (33 937 ha), Rinca Island (19 825 ha) and Padar (2017 ha).

**Land Tenure** Government-owned.

**Physical Features** The park comprises a group of islands, the three largest of which (Komodo, Rinca and Padar) have coastlines dominated by rugged, rocky shores sloping relatively steeply into the sea. Beneath the water the slope continues down to 15-20 m where it usually flattens out to a sandy bottom. In some places there are relatively sheltered bays with mangroves and beaches of white, coral sand; Komodo is the rockiest island and most of the sandy beaches are found on Padar and Rinca. In mangrove areas the water is mostly murky and the seabed dominated by sand and mud, with very few corals. Coral development is greatest in areas facing west and north, the most intact being those on the north-east coast of Komodo and the south-west coast of Rinca and Padar (Kvalvagnaes and Halim, 1979a). Further details of individual islands are given in Unesco (1986).

The seas around the islands are reported to be highly productive due to upwelling and a high degree of oxygenation resulting from strong tidal currents which flow through the straits. In some places the current is too strong even for boats with medium-sized engines, and would be fatal for swimmers and divers. The southern coasts of the three major islands are exposed for much of the year to big waves caused by the prevailing southerly winds from the Indian Ocean (Kvalvagnaes and Halim, 1979a). The Park is in one of the driest parts of Indonesia with 800-1000 mm rainfall (11 months having less than 200 mm). The north-west monsoon is from January to March. The weather is hot and dry from September to December; south-east winds are consistently strong and sea conditions are rough in August (IUCN, in prep.)

**Reef Structure and Corals** Kvalvagnaes and Halim (1979a) present data in tabular form on 26 marine survey sites. It appears that on most reefs the dominant corals are *Acropora* spp., especially the table-top coral *Acropora symmetrica*. *Millepora* spp. and *Porites* spp. are reported from many of the sites and *Fungia* spp. are present on reef slopes. In general the reef slope is weak to moderate, with corals growing to depths of between 6-15 m.

Borel-Best *et al.* (1985) and Van der Land and Sukarno (1986) found that the current-swept reefs consisted in places of an avalanche of coral fragments, only encrusting or low-branching species such as *Seriatopora caliendrum* and *Stylophora pistillata* being found living. At the entrance of Slawi Bay there are also strong currents and little coral growth. More protected reef slopes in the bay are dominated by *Cycloseris* and *Heteropsammia*; *Heterocyathus, Trachyphyllia, Catalaphyllia* and *Goniopora* are of secondary importance. At the north-eastern cape of Komodo, the fringing reef has a high species diversity including branching *Acropora, Hydnophora, Seriatopora, Caulastrea*, massive *Porites*, Faviidae, plate-like *Echinophyllia, Merulina, Pachyseris* and many Fungiidae.

The reefs off Gili Lawa Laut are very variable. The southern bay is very sheltered with coral cover of over 5%. Large stands of *Pachyseris, Echinopora, Mycedium, Echinophyllia* and *Montipora* are found intermixed with loose thickets of *Acropora* spp. The northern reefs are more exposed and have a spur and groove structure, hard coral cover being dominated by *Porites, Seriatopora* and *Acropora*.

The south of Eastern Bugies Island also has strong currents and lower coral cover, except on the upper reef slope close to the shore where *Acropora* was fairly common with large colonies of *Oxypora* and *Lobophyllia*.

**Noteworthy Fauna and Flora** Whales are regularly observed in the region of Komodo, including Blue and Sperm Whales. About ten species of dolphin are reported to occur in the area, as well as dugongs *Dugong dugon* and turtles. Sharks are abundant (Kvalvagnaes and Halim, 1979a). Terrestrial fauna and flora are described in Unesco (1986); the park is best known for the Komodo Dragon *Varanus komodoensis*.

**Scientific Importance and Research** The Komodo reefs were visited by the Snellius II Expedition in 1984 (Borel-Best *et al.*, 1985). Although the reefs do not have a particularly high coral species diversity, they are interesting because of their wide variety of community structure within a small area.

**Economic Value and Social Benefits** Some 1000 people live in the park; their principal occupations are fishing and collection of other marine products, such as molluscs and algae (for agar-agar production) (Kvalvagnaes and Halim, 1979a). Tourism is increasing (1500 visitors in

1984), but the potential is high, and is expected to expand further. Tourists come principally to see the Komodo Dragon (Unesco, 1986).

**Disturbance or Deficiencies** Large areas of Komodo's reefs have been destroyed or degraded by dynamite fishing. In places around Papagaran Island (outside the park) as much as 80% of the corals have been destroyed, while within the park, reefs on the west coast of Komodo and the east and north coast of Padar have been seriously damaged. For example, approximately 90% of corals are reported to have been destroyed between depths of 3-11 m on the north-east point of Pulau Padar. Chinese shell-collecting companies, previously based on Rinca, have now moved to Sumbawa and the shell grounds around Komodo are reported to be exhausted (Kvalvagnaes and Halim, 1979a; Borel-Best *et al.*, 1985).

Large areas on the islands have been converted to grassland as a result of illegal felling of timber and fires deliberately started by poachers hunting Timor Deer *Cervus timorensis*. This leads to serious erosion (Unesco, 1986), which could damage reef communities and other marine habitats.

**Legal Protection** Declared a National Park on 6.3.80 but legislation enabling the establishment of national parks is still lacking. Subsistence fishing by local people is permitted in certain areas, by approved methods. Removal of shells, corals or other marine life is prohibited (Kvalvagnaes and Halim, 1979a). Designated in January 1977 as a Biosphere Reserve.

**Management** Local administration: Chief Ranger/Superintendent, Jl. Jend, Subirwan No. 87, Labuan Bajo Ruteng, Nusa Tenggara Timur. Park headquarters and staff accommodation have been established on Komodo and a management plan has been produced. A permit is required for entry, available from PHPA offices or the park itself (Unesco, 1986).

**Recommendations** A zoning system for marine areas has been proposed and will follow the scheme that is being implemented for terrestrial areas. Intensive use zones, off shore from the terrestrial intensive use zones, will be used for anchorage and passage of boats. Wilderness and sanctuary zones will be established in a similar way. The terrestrial zoning scheme is given in UNDP/FAO (1982e). The marine extension of the park is considered a first order priority (Salm and Halim, 1984a).

### PULAU MOYO WILDLIFE RESERVE

**Geographical Location** 3 km off the north coast of Sumbawa; 8°05'-9°05'S; 115°46'-119°10'E.

**Area, Depth, Altitude** 18 765 ha (terrestrial); max. alt. 648 m.

**Physical Features** Pulau Moyo is a moderately uplifted coral island and is described in IUCN (in prep.). The area has a tropical monsoon climate, with a mean annual rainfall of 1250 mm in lowland areas. There is no information on the marine environment.

**Reef Structure and Corals** No information.

**Noteworthy Fauna and Flora** Terrestrial fauna and flora of the reserve are described in IUCN (in prep.). *Tridacna gigas* may occur (Usher, 1984).

**Scientific Importance and Research** No information.

**Economic Value and Social Benefits** No information.

**Disturbance or Deficiencies** No information.

**Legal Protection** The island was established as a reserve 20.8.75 under Ministry of Agriculture Decree 349 KPTS/UM/8/1975.

**Management** No information.

**Recommendations** A marine extension has been proposed and is listed in Salm and Halim (1984a and c) as a Fourth Order Priority.

# SULAWESI

### ARAKAN PROPOSED WILDLIFE RESERVE

**Geographical Location** South-west of Manado, at the north-eastern tip of Sulawesi; 1°22'N, 124°30'E.

**Area, Depth, Altitude** 16 000 ha (Salm and Halim, 1984c), including 2206.5 ha reef, 412.5 ha mangrove. Reefs extend from sea-level to about 15-20 m, and seabed depth exceeds 40 m within 250 m of the reef crest (WWF, 1981).

**Physical Features** The coastline of the proposed marine sanctuary is about 16 km in length and comprises bays, sandy beaches, rocky bluffs, estuaries and tidal flats. It is fringed by a reef that extends to 3.6 km offshore, is penetrated by deep inlets and has several detached reefs to the seaward side. Water clarity is 1 m in the mangrove, 8-20 m over the reef. The sea temperature is 27-28°C. Currents are easterly to north-easterly throughout the year, and the area is relatively sheltered from storms (WWF, 1981).

**Reef Structure and Corals** The reef flat emerges in places at low tide and is dominated by seagrass, with outcrops of *Acropora* and *Porites*. Coral communities on the reef crest are mixed but *Acropora, Pocillopora, Turbinaria* and *Millepora* are common. In sheltered areas *Porites* and *Pavona* are dominant. At the eastern end of the Ambon complex the reef fronts are sheer (WWF, 1981).

**Noteworthy Fauna and Flora** Dugongs *Dugong dugon* are reputed to be common towards the west end of the Arakan complex where there are extensive seagrass beds and an abundance of inlets and bays in which the animals can shelter. Turtles occur sporadically in the area (WWF, 1981). The reefs support a rich molluscan fauna, including various commercially important gastropods and the bivalves *Tridacna* spp. and *Hippopus hippopus*.

Vertical reef faces support a diverse invertebrate fauna. The mangroves are well developed, with at least six species occuring in the area (WWF, 1981).

**Scientific Importance and Research** No information.

**Economic Value and Social Benefits** The Arakan reef and mangrove complex is extremely important for local fishermen, who take fish, molluscs and turtles for their own consumption and for sale in local markets. The reefs are occasionally visited by recreational divers. Mangroves are heavily cut for wood to build boats and houses and also for firewood and charcoal production (WWF, 1981).

**Disturbance or Deficiencies** The reefs are heavily fished and there is a noticeable dearth of the most important edible fish, such as serranids, lutjanids, lethrinids, carangids and siganids. Dynamite is still used occasionally and other forms of fishing include hook and line, basket trap, speargun and net fishing. Some of these cause little damage although spearfishermen, who walk along the edge of the drop-off, break the corals. Net fishing involves intensive activity over the reefs. Boats are anchored on, or poled over, the reef and nets are weighted to the coral substrate. Fish are driven into the net by swimmers and the net is then hauled into the boat. All these activities cause coral breakage and result in capture of unwanted juvenile reef fish. Corals are also broken and reef fauna disturbed by people walking over the reef flat at low tide in search of molluscs (WWF, 1981).

Although turtles are not a consistent feature of the area they are hunted deliberately within the Arakan area. The Saltwater Crocodile *Crocodylus porosus* used to occur in the mangrove forest at Arakan but has been exterminated through hunting. The mangrove is being degraded as a result of heavy cutting, which could have damaging secondary effects on fish in adjacent reefs and nursery areas (WWF, 1981).

**Legal Protection** None.

**Management** No information.

**Recommendations** It is recommended that a wildlife reserve is established to the 200 m depth contour or 25 km seawards, whichever is furthest from shore, to include the mangrove forest, reef flats and reefs. A Dugong/reef/mangrove sanctuary could be established in the west, while the eastern part could be designated a Fishery Zone, in which hook and line, net or raft fishing are permitted (WWF, 1981). The Arakan area is listed in Salm and Halim (1984a) as a "First Order Priority Area".

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## KEPULAUAN BUNAKEN PROPOSED MARINE RECREATION PARK

**Geographical Location** Close to Manado, north-eastern tip of Sulawesi; 1°37'-1°47'N, 124°4'-124°48'E.

**Area, Depth, Altitude** Total area of about 49 375 ha (WWF, 1981) or 81 000 ha (Salm and Halim, 1984c) including 3781 ha island and mangrove, and 3728 ha coral reef. Reefs extend from sea-level to a depth of at least 25 m. In places depth exceeds 200 m within 500 m of the reef crest. Manado Tua is the highest island with a maximum altitude of 822 m (WWF, 1981).

**Physical Features** There are four main islands in the proposed park. Manado Tua, a steep island in the form of a truncated cone, is in the south-west. Pulau Bunaken, to the south of the group, is low, except for a hill rising to 110 m at the west end. Adjacent, to the east, is the tiny low-lying island of Siladen. All three islands are surrounded by narrow fringing reefs. The widest reef (1.5 km) is found off south-west Bunaken. Pulau Mantehage is a flat island, half of which is covered by mangrove, and has a fringing reef which extends nearly 3 km from the north side, where there is a shallow lagoon (2-6 m in depth). Pulau Nain is a saddle-shaped island 196 m high, surrounded by a lagoon at least 15 m deep. Beyond the lagoon is a barrier reef, on the east side of which is the islet Pulau Nain-Kecil. Water clarity is 25+ m over seaward reefs, 12 m in Nain Lagoon and 2-3 m in Mantehage Lagoon. Currents are variable and can be strong with dangerous eddies. The area is relatively sheltered from storms (WWF, 1981). Additional information is given in Salm and Usher (1984).

**Reef Structure and Corals** Reef flats emerge at low tide. The fore-reef is mostly vertical with terraces (shallowest at 25 m), especially on north-facing reefs. In most areas within the proposed park the reefs have no clearly dominant coral species and communities are typically diverse and mixed. Exceptions are found on the sheltered reefs surrounding Nain Lagoon where the reef crest is constructed of flat-topped massive corals, principally *Porites* but including *Goniopora, Favia* and *Lobophyllia*, encrusted by other corals. Below this coral rim the Nain lagoonal reef is dominated by branching corals, especially fragile *Acropora* spp. growing to a height of 1.5 m, and whorled or vase-shaped corals, primarily *Montipora foliosa* and *Echinopora lamellosa*, reaching a height of 2 m (WWF, 1981).

Where the fore-reef slopes gradually to 10-15 m, relatively small patches can be dominated by one or an assemblage of several coral species. This is particularly true on the more sheltered south and east sides of reefs. For example, the lower fore-reef slope (10-15 m) of east Manado Tua is dominated by an assemblage of tabular *Acropora* species and whorled *Echinopora, Montipora* and *Turbinaria*, while an unusual assemblage of *Plerogyra* and *Euphyllia* dominates an indentation in this reef. The slope off south-east Nain is dominated by a pure stand of *Montipora foliosa*. Where the fore-reef is vertical, it is generally dominated by invertebrates other than hard corals (WWF, 1981).

**Noteworthy Fauna and Flora** Coral reef fish are plentiful and diverse and probably reach their maximum diversity along the top of the sheer fore-reef at south Bunaken. The most outstanding feature of the Bunaken Island complex is the rich invertebrate fauna of the vertical fore-reef. These sheer walls with their small caves and overhangs are covered by an enormous variety of sponges, tunicates, crinoids, hydrozoans, alcyonarians, antipatharians and anemones. Gastropods, notably *Cypraea* spp., *Conus* spp., *Trochus* spp, and *Turbo* spp., *Lambis chiragra* and *Ovula ovum*, are common at certain sites on the reefs. *Tridacna* spp. and *Hippopus hippopus* occur throughout the area

(WWF, 1981). Turtles occur sporadically in the area. Seagrasses are found on all reef flats and in shallow lagoonal habitats. Half of Pulau Mantehage is covered by mangrove forest, dominated by *Rhizophora*. The Saltwater Crocodile *Crocodylus porosus* occurred until about 1979 (Salm and Usher, 1984; WWF, 1981).

**Scientific Importance and Research** No information.

**Economic Value and Social Benefits** 10 500 people live on the Bunaken Island complex, and their livelihoods depend heavily on reef fisheries and mangrove cutting. Marine tourism, especially snorkelling and SCUBA diving, is being developed around the islands by the Tourism Department and Nusantara Diving Centre of Manado (WWF, 1981; Whitten *et al.*, 1987).

**Disturbance or Deficiencies** The reefs are heavily fished and there is a noticeable lack of the most important food fish, such as serranids, latjanids, lethrinids, carangids and siganids. Corals are being damaged by fishermen, mostly as a result of net fishing which involves intensive activity over the reef. Boats are anchored on, or poled over, the reef and nets are weighted to the coral substrate. Fish are driven into the net by swimmers and the net is then hauled into the boat. All these activities cause coral breakage and result in capture of unwanted juvenile fish. The anchors of diving boats and divers standing on corals are also damaging shallow reef areas. In addition, there is disturbance and breakage of corals on reef flats by people walking over them at low tide in search of molluscs. Reef flats like those south of Bunaken are being stripped of life (WWF, 1981). A study by Lalamentik (1985, cited in Whitten *et al.*, 1987) has shown that reefs have noticeably more dead coral near human habitation than those further away.

The mangrove on Pulau Mantehage is being degraded as a result of heavy cutting. This could have damaging secondary effects on adjacent reefs and on nursery areas for fish. The Saltwater Crocodile may have been hunted to extinction (WWF, 1981).

**Legal Protection** None, although it has been declared as a Marine Park (see below).

**Management** As a result of lobbying by the Nusantara Diving Centre, the port authorities have forbidden large ships to pass through the straits between Manado and the Bunaken Islands, where the most spectacular reefs are located (Whitten *et al.*, 1987).

**Recommendations** Detailed recommendations for the area, listed in Salm and Halim (1984a) as a "First Order Priority Area", are given in Salm and Usher (1984) and WWF (1981). The conservation value of the reefs is diminished by the extent of damage to shallow water corals (1-4 m depth), but the habitats and species are considered to be highly important at a provincial level. The area was declared as a marine park by Decree of the Provincial Governor in 1980, but has not yet been established; it is also proposed by PHPA as a Marine Recreational Park at the national level (Salm and Usher, 1984; Salm, 1985).

It is suggested that the Governor's Office and the Dinas Pariwisata in Manado, as well as the Tourism Department and the Nusantara Diving Club, with guidance from PHPA, should be responsible for planning, administration and management of the park. The boundary should extend from 20 m inland to 25 km seaward of the reef crest around all islands in the complex, and all intervening waters should be included in the park. It is recommended that a management plan should be formulated. A zoning scheme has been proposed by Salm and Usher (1984) and Salm (1985) which includes Snorkelling-Diving Zones, Conservation Zones, Reef Fishing Zones and Deep Sea Fishing Zones. All approved fishing activities and approved mangrove harvest sites should be zoned and regulated. Net fishing on reefs, spearfishing and dynamite fishing must be prohibited. It is suggested that the Fisheries Department should encourage deep sea fishing among those islanders traditionally fishing on the reefs. Diving and snorkelling should be restricted to approved sites which should be buoyed and monitored; ten sites are recommended in Salm and Usher (1984), the locations to be determined by the Nusantara Diving Club who could also help with their installation. Siladen should be studied as a possible site for the development of a village for divers. The WWF (1981) report includes a conceptual design as a starting point for the park, and outlines considerations that should be made during the formulation of the management plan. Usher (1984) considers that the area is a high priority for the conservation of reef invertebrates and recommends that remaining Giant Clam *Tridacna gigas* individuals should be collected and maintained in a well-guarded breeding enclave. There is a need for marine environmental education, as many of the fishermen apparently do not appreciate the economic value of the reefs in terms of tourism (Rondo and Sondakh, 1985, cited in Whitten *et al.*, 1987).

## KEPULAUAN TOGIAN PROPOSED MARINE MULTIPLE-USE RESERVE

**Geographical Location** North-east of Ampana, off the north coast of central Sulawesi; 0°10'-0°40'S, 121°32'-122°12'E.

**Area, Depth, Altitude** 200 000 ha (Salm and Halim, 1984c); the boundary would extend from 1 km inland to 10 km seawards, or to the 200 m isobath, whichever is the greatest. Reefs extend at least to 25 m. The highest peak is Buntu Togian, 542 m (UNDP/FAO, 1982c).

**Physical Features** There are seven principal islands in the Togian Archipelago. From the west these are Pulau Una Una, Pulau Batudaka, Pulau Togian, Pulau Talatakoh, Pulau Waleakodi, Pulau Weleabahi and Pulau Puah. All of these are hilly and some are mountainous, and they are surrounded by a number of small limestone islands and islets. The archipelago lies on a plateau less than 200 m deep, except for Pulau Tampan which is a steep, rocky island lying west of Batudaka and separated from it by a channel more than 200 m deep (UNDP/FAO, 1982c).

Four major reef types occur in the area: barrier reef, atoll, fringing reefs and patch reefs. The plateau on which the main islands lie is bordered by an almost continuous barrier reef lying close to the 200 m depth contour, This generally lies about 5 km off shore but extends in places as far as 15 km from the nearest land.

Depths inside the reef are usually less than 50 m off Batudaka, Togian and Talatakoh Islands but increase to over 100 m around the eastern islands. A separate small barrier reef surrounds a deep (27 m) lagoon off the north of Tampan. There are two atolls off the north-west side of the plateau, both with a deep lagoon surrounded by shallow reef flat. Fringing reefs surround most islets and border almost all the coastline of large islands. Sea-level and submerged patch reefs are numerous within the barrier reef. A detailed map showing the distribution of reefs and reef systems is included in UNDP/FAO (1982c).

**Reef Structure and Corals** The barrier reef reaches the surface in many places, but lacks boulder or shingle ramparts, algal ridges and spur and groove formations which characterize reefs in areas of strong winds and large waves. The reef flat is formed of living corals, including *Seriatopora, Stylophora, Pocillopora verrucosa, Acropora* and *Porites*. These surround sandy or rubble patches. The atolls have two distinct reef communities. The lagoonal side of the reef flat is dominated by slender branching corals (principally *Acropora*, but including *Montipora, Porites* and *Clavarina*) and plate corals (*Echinopora lamellosa, Montipora* and *Mycedium*). Seaward communities are dominated by tabular corals *Acropora* spp., small robust branching corals and plate corals. Fringing reefs vary little except for those in bays, which are dominated by boulder and branching *Porites* and harbour uncommon genera such as *Madracis* and *Palauastrea*. These bay reefs merge into beds of seagrass and mangrove towards the shore. Those patch reefs that reach the surface resemble in structure and species composition either barrier or fringing reefs, depending on which is closer (UNDP/FAO, 1982c).

Coral diversity varies little among the different reef forms. A total of 59 genera and subgenera and 115 species were found at seven sites, which is relatively low. However, the UNDP/FAO survey was carried out without SCUBA equipment and it is likely that many other species occur in these clear waters. Three species, *Pavona minuta, Turbinaria peltata* and *Hydnophora exesa*, were found only on the atoll reef, whereas 51 species were found only on fringing reefs. Six species, *Palauastrea ramosa, Madracis* sp., *Echinophyllia* sp., *Polyphyllia talpina, Pavona decussata* and *Montrastrea valencienesi*, were found exclusively on sheltered bay reefs. *Palauastrea* has not previously been reported for Indonesia. Two species, *Favia pentagonia* and *Turbinaria stellulata*, were specific to the barrier reef (UNDP/FAO, 1982c). Early descriptions of the reefs are given in Umbgrove (1939a and 1940).

**Noteworthy Fauna and Flora** Babirusa *Babyrousa babirussa* occur on the islands (Thornback and Jenkins, 1982). Dugongs *Dugong dugon* are reputed to be common, particularly along the south coast. Green Turtles *Chelonia mydas* and Hawksbills *Eretmochelys imbricata* nest in relatively low numbers around the western islands. Saltwater Crocodiles *Crocodylus porosus* are reputed to occur around the islands and are said to frequent lagoons, semi-enclosed coves and other mangrove habitats. The Coconut Crab *Birgus latro* apparently breeds in large numbers on all islets and the rocky capes of larger islands. The clams *Tridacna squamosa* and *T. crocea*, and the Horse's Hoof Clam *Hippopus hippopus* are relatively common but *T. gigas* is rare. Trochus, *Trochus niloticus* and pearl oyster *Pinctada margaritifera* shells are uncommon (UNDP/FAO, 1982c; Usher, 1984). Two living Giant Tritons *Charonia tritonis*, several harp shells *Harpa costata* and many tiger cowries *Cypraea tigris* were found during the UNDP/FAO survey (UNDP/FAO, 1982c).

**Economic Value and Social Benefits** All the main islands and some of the smaller ones are inhabited. Subsistence fishing and small-scale commercial fishing for fish, molluscs and holothurians is important. Non-residents occasionally visit the Togian Islands to collect commercially valuable shells. Coconut Crabs are occasionally collected by residents of the islands and fishermen from outside the area. Turtles and turtle eggs are collected by the islanders. The islands and reefs are very attractive, and have great potential for the development of tourism (UNDP/FAO, 1982c).

**Disturbance or Deficiencies** Explosives are used for fishing, but only in the eastern part of the island group. In most areas the corals are in excellent condition. However, many valuable reef species (e.g. carangids, scomberorids, serranids, lutjanids and barracudas, trochus, pearl oyster shells and giant clams) are intensively harvested and consequently rare or even absent on many reefs. Certain families of fish are rare on many reefs, particularly those close to the main islands, but are more common on the two atolls and the barrier reef. Turtles, turtle eggs and Coconut Crabs are collected, the latter for export to the mainland (Usher, 1984). Babirusa forest habitat is being cut and replaced by coconut and other plantations (UNDP/FAO, 1982c). The recent eruption of a volcano on Pulau Una-Una has led to an influx of refugees to the Togian area (Usher, 1984).

**Legal Protection** None.

**Management** None.

**Recommendations** The Togian Islands contain an extensive area of well-developed and little-damaged reef with high conservation value. A proposal has been made to establish a Marine Multiple-Use Reserve (Salm and Halim, 1984c) which would include all the islands and reefs and extend from 3 km inland to 10 km seawards or to the 200 m isobath, whichever is further. The collection of Coconut Crabs should be prohibited except on Batudaka, Togian and Talatakoh, where it would be restricted to island residents for non-commercial purposes. The collection of pearl oysters, trochus and clams should be prohibited, except by residents in designated areas. Fishing would be excluded from certain conservation areas, which would function as breeding sites for commercially valuable species for the replenishment of depleted stocks in fishing zones. Expansion of coconut plantations or other plots should be prohibited on all smaller islands lying off Batuduka, Togian and Talatakoh to safeguard the remaining coconut crab and Babirusa habitats (UNDP/FAO, 1982c). The reserve could be a test case for development of invertebrate fisheries on a sustainable basis, although the influx of refugees and remoteness of the islands will hamper management (Usher, 1984). The Togian Islands are listed in Salm and Halim (1984a) as a "First Order Priority Area".

**PULAU PULAU SPERMONDE - PULAU SAMALONA PROPOSED MARINE NATIONAL PARK**

**Geographical Location** West of Ujung Pandang, off the south-western coast of Sulawesi Selatan in the Makassar Straits; 5°30'S, 119°10'E; Pulau Samalona is at 5°s, 119°10'E.

**Area, Depth, Altitude** 100 000 ha.

**Physical Features** The Spermonde Archipelago (Kepulauan Sankarang) consists of four rows of about 100 coral islands, submarine reefs, patch reefs and fringing reefs. The form of the islands and reefs is strongly influenced by prevailing winds. The coral structures have formed on a broad sand shelf continuous with and sloping to seaward of a coastal plain for a distance of 50-70 km into the Makassar Strait. Large quantities of sand may be shifted on to living reef flats altering their nature considerably (Umbgrove, 1930a; Wijsman-Best *et al.*, 1981). Sea-level changes have been described (De Klerk, 1985).

Coral growth is generally vigorous on the west side of reefs where currents are fairly strong and sedimentation limited, but there is little development of a reef flat. On the east, coral growth is poor to non-existent, due to high rates of sedimentation. The south-facing reef flat is usually well developed but the most extensive reef flats face to the west (Wijsman-Best *et al.*, 1981).

**Reef Structure and Corals** The reefs have been described by Umbgrove (1930a) and Moll (1983). A total of 262 species of scleractinians in 78 genera and subgenera have been recorded, an extremely high diversity (Moll and Borel-Best, 1984, cited in Whitten *et al.*, 1987).

**Noteworthy Fauna and Flora** Dugongs *Dugong dugon*, nesting Green *Chelonia mydas* and Hawksbill *Eretmochelys imbricata* Turtles and the Lesser Frigate Bird *Fregata ariel* occur in the area (Salm and Halim, 1984a). Green turtles nest on Pulau Samalona and there is a diverse invertebrate fauna on the surrounding reefs (Usher, 1984).

**Scientific Importance and Research** Research into various aspects of the reefs and corals of the archipelago is being carried out under a joint Netherlands-Indonesia programme (the Buginesia Project) in association with Hasanuddin University of Ujung Pandang. An Oceanographic Department has been set up with a marine station and staff to carry out research on mangroves and coral reefs around Sulawesi (De Klerk, 1983; Moll, 1983; Van der Land and Sukarno, 1986; Wijsman-Best *et al.*, 1981). The Snellius II expedition visited the area in 1984 (Borel Best *et al.*, 1985).

**Economic Value and Social Benefits** Most of the islands are densely populated, the total population being about 40 000, and fishing is an extremely important activity. The archipelago is considered to have the largest reef-based fishery in Indonesia (Whitten *et al.*, 1987). Fishing activities on the islands of Barang Lompo and Barang Caddi are described by Davie and Mustafa (1984), the latter being entirely reef-based. The reefs close to Ujung Pandang are a source of limestone for building (Wijsman-Best *et al.*, 1981). There is considerable tourist potential (Salm and Halim, 1984c).

**Disturbance or Deficiencies** Dynamite fishing is carried out and is causing considerable damage. Reef flats are heavily exploited for molluscs and other reef fauna. Living corals are being collected as a source of limestone for construction of roads and houses and are often extracted with explosives. Large areas of mangrove are being cut along the coast of South Sulawesi and this, together with heavy land erosion, produces considerable quantities of sediment which could be damaging to reef communities (Borel-Best *et al.*, 1985; Wijsman-Best *et al.*, 1981).

**Legal Protection** None.

**Management** None.

**Recommendations** Wijsman-Best *et al.* (1981) stress that a management plan is required for the Spermonde Archipelago, in view of the growing demands by industry, tourism and an increasing population. A proposal has been made to establish a Marine National Park in the area (Salm and Halim, 1984c) which is listed in Salm and Halim (1984a) as one of Second Order Priority. The work being carried out at Hasanuddin University will provide a good basis for management planning (Van der Land and Sukarno, 1986).

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**TAKA BONE RATE PROPOSED MULTIPLE-USE MANAGEMENT AREA**

**Geographical Location** The Flores Sea, east of the southern tip of Selayer Island, and approximately halfway between Sulawesi and Flores; 6°37'S, 121°4'E.

**Area, Depth, Altitude** 222 000 ha (40 mi long); Salm and Halim (1984c) recommend an area of 205 200 ha for protection; reefs extend from sea level to an unspecified depth. Water depth around the atoll is 20-80 m (UNDP/FAO, 1982d). The cays associated with the atoll are low lying.

**Physical Features** The atoll comprises a complex system of patch reefs, barrier reefs and faroes on which are developed 21 sand cays. A second, smaller atoll lies about 2 km off the north-east corner of the main atoll. The largest sand cays have coconut plantations, and at least nine are permanently inhabited. Sea-level reefs are exposed at low tide and others have sand banks, which range in size and development from small, periodically exposed talus ridges to large sand banks and vegetated cays. Sea-level reefs line the perimeter of the main atoll from the centre of the west side around the north and along the eastern edge. A complex system of large sea-level reefs occupies the central portion of the atoll, with extensive reef flats or central lagoons. The margin of the atoll slopes steeply to great depths, but is apparently nowhere sheer (UNDP/FAO, 1982d). There are strong currents in the north-east (Borel-Best *et al.*, 1985).

**Reef Structure and Corals** The reef flats consist of extensive central sandy tracts with a rim of living coral around the outside. In general, the outer perimeter of the reef is dominated by large, massive boulders of *Porites* and some faviid corals, or by tabular *Acropora*. In more sheltered areas, staghorn corals or banks of leafy corals, such as *Montipora foliosa*, may dominate from the reef crest down the reef slope. Lagoonal reefs have essentially the same corals as outer reefs but the colonies of branching and leafy forms attain larger and more fragile proportions. Coral diversity is high and a total of 68 genera and subgenera and 158 species were recorded from the area, 65 genera and 149 species from Taka Bone Rate atoll alone (UNDP/FAO, 1982d).

The Snellius II Expedition found that the reefs around the sand cays Tarupa Kecil and Tarupa Besar had abundant soft corals, sponges and hydrozoans and a coral cover of about 30% at 10 m depth and up to 40% at the reef edge. At Pulau Tinanja there is an extensive reef flat, with variable reef communities and structures due to the influence of currents and winds. More than 70 coral species were found in the large lagoon west of Tarupa Besar (Borel-Best *et al.*, 1985; Van der Land and Sukarno, 1986).

**Noteworthy Fauna and Flora** The Green Turtle *Chelonia mydas* and Hawksbill Turtle *Eretmochelys imbricata* both occur in the area and nest on uninhabited cays, the extensive reefs and seagrass beds providing abundant grazing grounds and shelter (UNDP/FAO, 1982d). The north-eastern reefs are rich in fish (Borel-Best *et al.*, 1985).

A total of 121 species of gastropod mollusc, 78 species of bivalve and 1 scaphopod were recorded, including Nautilus, cuttlefish, squid and octopus. However, despite the high diversity, populations were low. Six of the seven species of giant clams were seen at Taka Bone Rate, the most abundant being the smaller species, *Tridacna crocea* and *T. maxima*. Living *T. squamosa, T. deresa, Hippopus hippopus* and *H. porcellanus* were seen at 100%, 50% and 70% of the survey sites, respectively, but never in great abundance. *T. gigas* is reported to occur on the reefs but no living specimens were seen. Commercially valuable mother-of-pearl shells, such as commercial trochus *Trochus niloticus*, green snail *Turbo marmoratus*, and pearl oysters *Pinctada maxima, P. margaritifera* and *Pteria* spp., were notable for their scarcity. Only one living trochus and five living *P. margaritifera* were seen during the survey. The most common gastropod species were strombids, particularly *Strombus luhuanus* and *Lambis* spp. The reef flats of uninhabited islands were particularly rich in gastropods, with species of the genera *Strombus, Oliva, Conus* and *Cymbiola* being abundant (UNDP/FAO, 1982d; Usher, 1984).

**Scientific Importance and Research** Taka Bone Rate is the largest atoll in Indonesia, and thus of considerable scientific interest. Some work was carried out there during the Snellius II Expedition (Borel-Best *et al.*, 1985).

**Economic Value and Social Benefits** The reefs of Taka Bone Rate atoll are remote from major population centres, but are heavily utilised by local islanders, and fishermen from further afield. Green Turtle *Chelonia mydas*, Loggerhead *Caretta caretta* and possibly Olive Ridley *Dermochelys coriacea*, are collected and kept in pens for sale to the Balinese (UNDP/FAO, 1982d). Hawksbill Turtles *Eretmochelys imbricata* are also caught, and tortoiseshell sent to Ujung Pandang in Sulawesi. The area is also important for fish, but there is no information on which species are taken.

The mollusc fauna is exploited by local and itinerant fishermen, including professional divers from towns such as Ujung Pandang. The meat of giant clams and a variety of other molluscs, including *Cassis cornuta, Chicoreus ramosus, Cymbiola vespertilio, Strombus luhuanus* and *Lambis lambis*, is eaten by the islanders. Dried clam meat is exported to neighbouring islands and mainland Sulawesi and dried octopus, sea cucumbers and mother-of-pearl shells are also exported. The shells of *Tridacna gigas* and large *T. deresa* and *T. squamosa* are stored on one of the islands (Pulau Jinatu), from where they are exported to Jakarta to be crushed and made into high quality floor tiles. Fishermen use shells of the triton *Charonia tritonis* as trumpets or export them for sale as souvenirs. Itinerant fishermen collect any species that are edible or have commercial value and professional divers specialize in mother-of-pearl shells and those of high souvenir value (UNDP/FAO, 1982d).

**Disturbance or Deficiencies** The marine resources of Taka Bone Rate atoll are unmanaged but heavily exploited. This has led to serious degradation of the coral reefs. The UNDP/FAO survey report (1982e) states that the reefs are too damaged to be of value to conservation, and the atoll is listed as a "Threatened Community" in the IUCN Invertebrate Red Data Book (Wells *et al.*, 1983).

Turtles have been hunted intensively and are now rare. The Loggerhead, and possibly the Olive Ridley, are both captured, despite being protected by Ministerial Decree. The use of explosives for fishing has severely damaged vast areas of coral reef and has decimated fish populations in shallower reef areas. The islanders claim that it is people from Flores who most frequently fish these reefs with explosives, and also maintain that the practice is declining because of increased difficulty in obtaining dynamite. The reefs have also been damaged by fishermen who smash corals while searching for molluscs. Certain of the larger species have been so intensively fished that they have become rare or locally extinct, particularly *Tridacna gigas* and *Charonia tritonis*, and it is likely that populations of *Cassis cornuta* and mother-of-pearl shells will be similarly devastated (UNDP/FAO, 1982d).

**Legal Protection** None.

**Management** None.

**Recommendations** It is considered that the Taka Bone Rate reefs are so degraded that it would not be worthwhile for the PHPA to embark on a major conservation effort. However, the area is proposed as a Wildlife Reserve by Salm and Halim (1984a) and is considered a First Order Priority. It is recommended that the PHPA discusses with the Directorate General of Fisheries ways to control destructive fishing methods. The area is considered a high priority for reef invertebrate conservation (Usher, 1984). Taka Bone Rate is one of the few known sites of the clams *Tridacna deresa* and *Hippopus porcellanus* in Indonesia and it is recommended that the PHPA should set aside an area of reef in the central part of the atoll as a sanctuary for the clams. This should include several of the central reefs east of Pulau Jinatu and, although having the protection of *T. deresa* and *H. porcellanus* as its principal objective, it should also protect a full range of local reef habitats and communities, including breeding stocks of valuable fish. If the sanctuary is established, village heads should be made responsible for its control and for preventing the capture of protected turtles and the collection of turtle eggs (UNDP/FAO, 1982d).

Various other measures are suggested which could help in the conservation of Taka Bone Rate atoll. For example, it is recommended that turtle landings on Bali should be rigorously monitored by the PPA and that severe penalties are imposed on those who trade in protected species. It is suggested that there should be a national ban on the operation of boats carrying groups of divers and diving equipment from ports, such as Ujung Pandang, to distant reefs, such as Taka Bone Rate atoll, for the collection of reef molluscs and corals. Exploitation of reef resources by itinerant fishermen should be banned by national legislation so that these resources can be safeguarded for local residents (UNDP/FAO, 1982d).

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## TANGKOKO-DUA SAUDARA STRICT NATURE RESERVE

**Geographical Location** On the northern tip of Sulawesi Utara, east of Manado; 1°03'N, 125°15'E.

**Area, Depth, Altitude** 8867 ha land, 1 250 ha marine extension; altitude ranges from sea-level to 1351 m (Gunung Dua Saudara).

**Land Tenure** Government-owned.

**Physical Features** The reserve is dominated by three volcanoes, of which Gunung Tangkoko is the most active. There are a number of fine, sandy beaches which change colour from black to white depending on the monsoon. Off shore are coral reefs. The rainy season is from November to March (IUCN, in prep.).

**Reef Structure and Corals** Corals vary from delicate forms in the sheltered waters of Batuangus cove to the stronger open-water corals facing the northern seas (IUCN, in prep.).

**Noteworthy Fauna and Flora** Terrestrial fauna and flora are described in IUCN (in prep.).

**Scientific Importance and Research** Studies on terrestrial fauna and flora have been undertaken (IUCN, in prep.).

**Economic Value and Social Benefits** No information.

**Disturbance or Deficiencies** No information.

**Legal Protection** The reserve was established 27.2.19 under Staatsblad No. 90 and the terrestrial part enlarged in 1978. It was enlarged again in 1982 to include a 500 m offshore extension. Plants and animals are fully protected (IUCN, in prep.).

**Management** Local administration: PPA section offices, Jl 20 Mei Teling, Manado. There are no visitor facilities at present. A management plan was produced prior to the declaration of the marine extension (WWF, 1979).

**Recommendations** Three zones are planned: a small development zone; a larger wilderness zone; and an extensive sanctuary zone. It is not known how these relate to the marine environment (IUCN, in prep.). Salm and Halim (1984a and c) recommend a further marine extension as a Third Order Priority to include additional reefs.

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## TANJUNG API STRICT NATURE RESERVE

**Geographical Location** Just north of Ampana on the north coast of Central Sulawesi (*see also account for* Togian Islands); 0°50'S, 121°50'E.

**Area, Depth, Altitude** 4246 ha.

**Physical Features** Headland fringed by coral reef.

**Reef Structure and Corals** The inner reef flat is dominated by small massive corals, principally faviids, but also *Porites, Seriatopora, Stylophora* and a variety of other types. The outer reef flat is dominated by larger massive corals, up to several metres in diameter, including *Diploastrea*, faviids, *Physogyra* and *Lobophyllia*. Branching and tabular *Acropora* is also present (UNDP/FAO, 1982c). Where the reef is narrow it drops from a depth of between 2 and 5 m to 20 m down a sheer fore-reef, which is undercut in places and pitted by caves. These overhangs, caves and sheer faces are covered by invertebrates. Where the reef is wider the slope is more gradual and vertical faces may be absent (UNDP/FAO, 1982c).

**Noteworthy Fauna and Flora** No information.

**Scientific Importance and Research** No information.

**Economic Value and Social Benefits** No information.

**Disturbance or Deficiencies** Patches of the reef are damaged, presumably by the use of explosives for fishing (UNDP/FAO, 1982c).

**Legal Protection** Established in 1977; it is not known whether reefs are included within current boundaries.

**Management** No information.

**Recommendations** The boundaries of the reserve should be extended 4 km from the coast in order to include the offshore reefs and other marine areas (UNDP/FAO, 1982c; Salm and Halim, 1984c); this is considered a First Order Priority by Salm and Halim (1984a).

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## TUKANG BESI PROPOSED WILDLIFE RESERVE

**Geographical Location** South-east of mainland Sulawesi Tenggara; 5°35'S, 123°50'E.

**Area, Depth, Altitude** 200 000 ha.

**Physical Features** An archipelago with numerous limestone islands and patch, fringing, barrier reefs and atolls (Salm and Halim, 1984a). The island of Binongko is flat, consists of limestone, and is surrounded by uplifted fossil reefs (Kuenen, 1933); its geology is described in Van der Land and Sukarno (1986).

**Reef Structure and Corals** Karang Kaledupa is an exposed reef without sand cays and with strong currents in tidal inlets. Coral cover is generally not high, and there is abundant sand, rubble, soft corals and sponges. Inside the reef there are extensive patches with high coral cover, consisting mainly of one or two species of *Acropora*. Off the islands of Binongko, there is an undisturbed reef terrace north of Taipabu, with abundant fish, octocorals, sponges and ascidians but low stony coral cover; *Porites* is fairly abundant but forms small colonies. Near Pulau Tomea, a reef flat with large coral colonies of Mussidae and other species backs on to a lagoon with fragile species, such as *Galaxea fascicularis* (Borel-Best *et al.*, 1985).

**Noteworthy Fauna and Flora** Turtles and Dugongs *Dugong dugon* are reported to occur in the archipelago (Salm and Halim, 1984a).

**Scientific Importance and Research** Research was carried out at the Tukang Besi Islands during the Snellius II Expedition 1984 (Borel-Best *et al.*, 1985). The islands have an important reef invertebrate fishery, itinerant divers coming from Pulau Butung (Usher, 1984).

**Economic Value and Social Benefits** No information.

**Disturbance or Deficiencies** Many reef invertebrates may have been overexploited (Usher, 1984).

**Legal Protection** None.

**Management** None.

**Recommendations** A proposal has been made to establish the archipelago as a wildlife reserve or Multiple Use Management Area (Salm and Halim, 1984c) and it is listed in Salm and Halim (1984) as a "Third Order Priority Area".

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# MALUKU

### ARU TENGGARA PROPOSED STRICT NATURE RESERVE/MARINE PARK

**Geographical Location** South-eastern part of the Aru Archipelago, which is situated in south-east Maluku, about 120 km south of Irian Jaya. 6°35-7°11'S, 134°12'-135°00'E.

**Area, Depth, Altitude** 250 000 ha (UNDP/FAO, 1981) or 200 000 ha (Salm and Halim, 1984c); water depth does not exceed 18 m. Maximum altitude of islands is 15 m (UNDP/FAO, 1981).

**Physical Features** The Aru Archipelago, unlike the other Maluku islands, lies on the continental Sahul shelf which also bears the landmasses of Australia and New Guinea. Immediately west of Aru the shelf is bordered by the deep sea trenches and troughs of the Banda Sea. To the east is the shallow Arafura Sea. The major part of the archipelago is formed by raised coral reefs of quaternary origin, fringed by living reefs, and has a total area of about 6000 sq. km, consisting of six larger islands, surrounded by many smaller ones. All the islands lie close together within an area measuring 180 km from north to south and 80 km from east to west. The proposed reserve is in the south-east and includes the coastlines of south-west Trangan, Koba, Baun and Workai islands and several small offshore islands, such as Penjuring, Jeh, Babi and Enu (IUCN, in prep.). The seabed between the islands and reefs is sandy or muddy (UNDP/FAO, 1981). The dry season runs from May to August.

**Reef Structure and Corals** Fringing reefs occur along the entire eastern side of the archipelago, and reach their maximum development between and around the south-eastern islands, within the proposed reserve boundaries. Small reef flats and reef edges occur around many of the islands, while extensive flats are found around Pulau Jin, Pulau Mar, Pulau Wolil and east of Pulau Workai (UNDP/FAO, 1981). The reef communities are characteristic of turbid water (IUCN, in prep.).

**Noteworthy Fauna and Flora** The Archipelago is one of the best remaining habitats for Dugong *Dugong dugon* in Indonesia and large populations still occur here, some within the proposed reserve. The Green Turtle *Chelonia mydas* and Hawksbill *Eretmochelys imbricata* are known to nest within the proposed reserve, and the Olive Ridley *Lepidochelys olivacea* and Loggerhead *Caretta caretta* occur in the archipelago. Two species of crocodile, the Saltwater *Crocodylus porosus* and New Guinea *C. novaeguineae* Crocodiles are known from Aru, *C. porosus* occurring within the proposed reserve area (UNDP/FAO, 1981). A total of 128 species of fish has been described. The pearl oyster *Pinctada maxima* occurs within the reserve and reef-associated invertebrates such as *Trochus niloticus* and holothurians are collected in the area (Usher, 1984). Terrestrial flora and fauna is described in IUCN (in prep.). There are 10 000 ha of mangrove and 40 000 ha of seagrass.

**Scientific Importance and Research** No information.

**Economic Value and Social Benefits** Aru is poor and undeveloped and the economy for most residents is at subsistence level, based on the gathering of sea products for consumption or trading. The major export products, in order of volume, are copra, seaweed, fish, sea cucumber, pearl and mother-of-pearl. Dugong, turtles and crocodiles are also used. Although residents are commonly engaged in the gathering of these products, export earnings benefit only a few local people, mainly of Chinese origin. Foreign, mainly Japanese companies, are involved in commercial fisheries and the cultivation and trade of pearl. About 5000 people living in 15 kampongs, which lie just outside the boundary, regularly fish within the proposed reserve. Cruise ships occasionally visit Pulau Enu, within the proposed reserve, because a deep water anchorage is available. These are the only tourists at present visiting the area because of its inaccessibility (UNDP/FAO, 1981), although there is considerable potential for further development of this industry.

**Disturbance or Deficiencies** The major disturbance is from fishing and exploitation of marine resources. A pilot study in 1979 (Compost, 1980), showed that, although protected, the dugong population in Aru is severely threatened by excessive hunting for its meat and especially its valuable teeth. Turtles are harpooned on their feeding grounds and caught on nesting beaches, and their eggs are collected. Saltwater Crocodiles are severely hunted, because of the value of their skins. New Guinea Crocodiles are protected, but are probably also inadvertently captured (UNDP/FAO, 1981). Intensive collecting of pearl oysters has seriously depleted populations (Usher, 1984).

**Legal Protection** The Pulau Baun Bird of Paradise Reserve (13 000 ha), established in 1974, is contiguous with the proposed reserve.

**Management** No information.

**Recommendations** A proposal for a reserve was made in 1981, but no specific recommendations were made regarding overall management or zoning of the area. It was emphasized that measures should be taken to protect endangered species, such as the dugongs, turtles and crocodiles, in strictly protected sanctuary zones and that there should be traditional use zones for local fishing communities. A seaweed farming scheme for *Eucheuma* has been suggested as an alternative to the hunting of dugong and crocodiles. In the long term, the marine conservation area could be linked with the terrestrial reserve on Pulau Baun and other proposed conservation areas on Pulau Kobroor to form a single conservation unit (UNDP/FAO, 1981). Salm and Halim (1984a) recommend the establishment of a Strict Nature Reserve and Marine Park and consider it a "First Order Priority Area". Shallow-water offshore sanctuary zones should be established for *Pinctada maxima* and the area is considered a high priority for reef invertebrate conservation (Usher, 1984).

## PULAU BANDA STRICT NATURE RESERVE AND MARINE PARK

**Geographical Location** Approximately 120 km south of the south-east coast of Seram; 4°30'S, 129°40'-130°E.

**Area, Depth, Altitude** 2500 ha are protected and a proposal has been made to incorporate a further 7700 ha into the Park; it is proposed that 15 000 ha should be protected at Pulau Suanggi (Salm and Halim, 1984c). No data are available on the depth of the reefs. The highest peak, Gunung Api, which lies adjacent to the proposed extension, is 676 m.

**Physical Features** The Banda Islands include the central Banda Besar, Neira, Gunung Api, Pisang group, where the Marine Park is located, and a number of distant islands, including Run, Ai, Suanggi and Hatta. At present the Marine Park boundary runs along the seaward margins of Pulau Banda Besar, Gunung Api, Pulau Neira and Pulau Syahril. The proposed extension would not incorporate the islands but would include all the marine areas between and outside the islands, to a distance of 2 km from their outward facing coastlines (UNDP/FAO, 1982f).

The central islands are volcanic in origin and evidently represent three separate eras of volcanic activity. Pulau Banda Besar is apparently the remnant of the original volcano, while Pulau Neira is the remnant of another volcano inside the original caldera. Gunung Api, dominating the island group with the sheer slopes of its volcanic cone, is the youngest volcano and is inside the inner Neira Caldera. Fringing reefs occur around the islands (UNDP/FAO, 1982f). The rainy season is from May to October.

**Reef Structure and Corals** Pulau Banda Besar has the widest reef flat and greatest reef development. Reef development on Pulau Neira is limited to the outward-facing north, south and east sides, while Gunung Api shows the least reef development. A total of 118 corals from 61 genera and subgenera has been reported from the Banda reefs and live coral cover is 85% and 100% on certain reefs. The reefs display a variety of habitats, which is to be expected considering the range in size and age of the islands and the different degrees of exposure to prevailing winds, waves and currents (UNDP/FAO, 1982f). No ecological data on the reefs are available. The reserve was based on the once famous coral gardens in the shelter of Lontar which are now degraded; the best beaches and reefs are now found around Suanggi, the furthest outlying island (Anon., 1982).

**Noteworthy Fauna and Flora** A total of 195 species of molluscs has been found on the Banda reefs and are listed in UNDP/FAO (1982f). Certain of the larger molluscs, notably the commercially valuable species such as *Tridacna squamosa*, *Pinctada margaritifera* and *Pteria* spp., occur on the reefs but are uncommon. The commercial trochus *Trochus niloticus* was also recorded, but there are no details of other reef fauna (UNDP/FAO, 1982f). Suanggi is an important nesting site for boobies *Sula* spp. and other seabirds; further information on the terrestrial fauna of the islands is given in Anon. (1982).

**Scientific Importance and Research** No information.

**Economic Value and Social Benefits** The Marine Park is surrounded by coastal villages and fishing is an important activity. Most fishing is with hook and line from small dugouts in deep water near coral or rocky reefs or with gill and seine nets in sheltered waters. Bait fish are caught with beach seines or over reefs with triangular lift nets. Fish traps are set on reef flats and anchored in place by boulders. There is a fishery for skipjack tuna during the calm season (October to April) for which boats carrying a crew of 15-20 men are used. Fishermen also collect molluscs from reef flats at low tide. There are two tourist hotels and several guesthouses. The owner of the Banda Neira Hotel is attempting to develop marine tourism in the islands (UNDP/FAO, 1982f).

**Disturbance or Deficiencies** Fishermen pose the greatest threat to the Marine Park. UNDP/FAO (1982f) report that reefs are largely undamaged, but Anon. (1982) states that those in the reserve are now degraded.

**Legal Protection** The Marine Park was established in April 1977 and the island has the status of Strict Nature Reserve (UNDP/FAO, 1982f).

**Management** At present there is no active management for the Pulau Banda Marine Park, but a PHPA house for a Kepala Resort is nearing completion on Pulau Neira. The PHPA Sub Balai office is on Ambon (UNDP/FAO, 1982f).

**Recommendations** It is recommended that the boundaries of the Pulau Banda Marine Park be extended (Salm and Halim, 1984c) to include all coastal waters and habitats around the central islands, to a distance of 2 km from their outer coastlines, with a zoning scheme as follows. A traditional fishing zone for residents of the central islands should be declared throughout the Marine Park, except within a radius of 500 m of mooring buoys. Thirteen snorkelling/diving zones are proposed, each consisting of a circle 1000 m in diameter, with a mooring buoy at the centre. The beach west of Malole on Pulau Neira should be declared a recreational area. Mining of coral, giant clam shells, sand and rock and the collection of turtles and turtle eggs should be prohibited within the Marine Park. Other recommendations for patrolling and monitoring are similar to those for the Pulau Pombo and Pulau Kasa Marine Parks. Permits to visit Pulau Banda would be obtained directly from the Kepala Resort in Banda (UNDP/FAO, 1982f). Salm and Halim (1984c) also recommend the creation of a separate strict marine reserve around Pulau Suanggi; this is considered a First Order Priority (Salm and Halim, 1984a).

## PULAU KASA WILDLIFE RESERVE AND MARINE PARK

**Geographical Location** Piru Bay, off the south-west coast of Seram and north of Ambon; 3°30'S, 128°20'E.

**Area, Depth, Altitude** 900 ha land, 1100 ha sea; it is recommended that a further 5600 ha are added to the Park, to include Pulau Babi and adjacent reefs. It has also been recommended that an area of 2500 ha should be protected at Pulau Babi. Reefs extend from sea level to an unspecified depth. Pulau Kasa is low lying; Pulau Babi has a maximum elevation of 131 m (UNDP/FAO, 1982f).

**Physical Features** Pulau Kasa is a sand cay surrounded by a fringing reef. A patch reef and Pulau Babi, with its fringing reef, lie 4.5 km and 8 km north of Pulau Kasa respectively, but are outside the current park boundary (UNDP/FAO, 1982f).

**Reef Structure and Corals** A total of 92 species of coral from 54 genera have been reported for the Pulau Kasa reefs (UNDP/FAO, 1982f) but the only ecological data is in a series of profile diagrams in Randall and Eldredge (1983). The diagram for Pulau Kasa shows a shallow reef flat and reef rim with mixed corals and some large coral heads. The fore-reef slopes gradually and the corals are more widely dispersed and of lower profile.

Pulau Babi is reported to have an excellent fringing reef along the north shore. This reef has a high percentage cover of living corals and drops absolutely sheer from a depth of about 2 to 15 m. Below this, it shelves very steeply to more than 30 m depth. The vertical face is covered with corals and various invertebrates, has caves and overhangs, and is split by narrow crevices (UNDP/FAO, 1982f). A profile diagram of this reef and the platform reef between Pulau Babi and Pulau Kasa is included in Randall and Eldredge (1983).

**Noteworthy Fauna and Flora** Turtles nest in low numbers on Pulau Kasa and the island is a roosting site for the Pied Imperial Pigeon *Ducula bicolor* and the Megapode *Megapodius reinwardtii*. A total of 154 species of mollusc has been found on the Pulau Kasa reefs. Some of the larger species, notably the commercially valuable *Tridacna squamosa, Pinctada margaritifera* and *Pteria* spp., are uncommon. The Horse's Hoof Clam *Hippopus hippopus* has also been recorded (UNDP/FAO, 1982f).

**Scientific Importance and Research** A preliminary survey was carried out by Kvalvagnaes and Halim (1979c).

**Economic Value and Social Benefits** Pulau Kasa is uninhabited, but is used a base by fishermen, who may camp for several days in succession in order to salt and dry their catch. Megapode and turtle eggs are collected from the island. Several large fish traps are set up permanently on the reefs, and fishermen collect molluscs from the reef flat. Pulau Babi, at present outside the park boundary, is reported to have high recreational potential (UNDP/FAO, 1982f).

**Disturbance or Deficiencies** The reef at Pulau Kasa and the patch reef north of the island have been damaged by dynamite fishing, and by boat anchors and poles. Molluscs are stripped from the reef flats at low tide which may deplete some species and damage the habitat. On the island itself megapode eggs are collected illegally, and the vegetation cleared for a variety of purposes (UNDP/FAO, 1982f).

**Legal Protection** In 1976 Pulau Kasa was declared a Wildlife Reserve and the surrounding reefs and sea a Marine Park. Subsistence fishing and collecting of reef fauna are allowed only by permit, and permits may also be issued by the PHPA for the collection of living plants and invertebrates for scientific purposes (UNDP/FAO, 1982f).

**Management** The PHPA has a Sub Balai office in Ambon and small rooms on Pulau Kasa. Pulau Kasa is patrolled about twice each month during the calm season, but from May to September rough weather prevents patrols from reaching the island.

**Recommendations** The reefs of Pulau Kasa appear to have little conservation value at a national level but the island is important for the conservation of megapodes. It is recommended that its status should be changed from Wildlife Reserve (Suaka Margasatwa) to Strict Nature Reserve (Cagar Alam), which would enable greater control of fishermen and bird poachers who now visit the islands (UNDP/FAO, 1982f).

It is recommended that the boundaries of the Pulau Kasa Marine Park should be extended to include Pulau Babi and the patch reef lying north of Pulau Kasa, and that a zoning scheme should be introduced. The reefs of Pulau

Kasa, Pulau Babi and the patch reef north of Pulau Kasa should be off limits to fishing. A snorkelling/diving zone should be declared to 200 m seaward of the reefs around Pulau Babi and the island itself should be designated as an intensive use zone. A wilderness zone should coincide with all reef areas which lie outside the snorkelling/diving zone. It should also be the zone for research and education. Mining of coral, giant clam shells, sand and rock, and harvesting of turtles, turtle eggs and other reef fauna would be prohibited throughout the Marine Park (UNDP/FAO, 1982f). Salm and Halim (1984c) recommend the establishment of a Marine Park at Pulau Babi, oriented towards tourism.

It is recommended that shelters, camping facilities and a PHPA guard post be established on Pulau Babi, so that Pulau Kasa can be retained as a megapode sanctuary. The PHPA should ensure that existing regulations are enforced immediately to prevent further degradation, and should initiate public relations programmes for the marine park so that the objectives and regulations become known to the residents of nearby villages. Rangers on patrol should carry information leaflets with them for distribution to visitors, and permits to visit the park should be issued from the Sub Balai office in Ambon. The UNDP/FAO management plan proposals stress that there must be constant monitoring of the effect of visitors on the reef at snorkelling/diving sites and on the islands, in order to determine whether there is any damage to corals or vegetation. Megapode and turtle nesting should also be monitored to determine population trends (UNDP/FAO, 1982f).

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## PULAU POMBO STRICT NATURE RESERVE AND MARINE PARK

**Geographical Location** Northern end of the Haruku Strait, between the islands of Haruku and Ambon; 3°31'S, 128°22'E.

**Area, Depth, Altitude** 1000 ha; reefs extend from sea-level to 20 m. Pulau Pombo is 0.5-1.0 m above sea-level (Sumadhiharga, 1971).

**Physical Features** Coral reefs at Pulau Pombo form an almost circular atoll and surround a 7 ha lagoon with a maximum depth of 22 m. There is a narrow opening in the reef to the north-east which is navigable by small boats. Pulau Pombo lies on the east side of the atoll (Sumadhiharga, 1971). A popular description of the island is given in Soedharma (1977).

Temperature (27-28°C) and salinity (32.5-34.5 ppt) of the lagoon from the surface down to 20 m is almost homogenous. The direction of main current flow in the lagoon is similar to that outside the lagoon, but in the reef area the current flows in a parallel direction with the reef margin. During the west monsoon the sea is rough at the reef edge, especially in the north-west and north-east, because the winds and currents are in opposition. This water movement can endanger the coral communities where fine sand and coral sediments of the shallow seabed are stirred up and make the water turbid. During the east monsoon the water is relatively calm and clear but strong surf may occur on the north-east- and south-west-facing reef where the currents and winds are again in opposition. The south-east reef is in a relatively sheltered area during both monsoons and turbidity is usually low (Sumadhiharga, 1971).

**Reef Structure and Corals** On the north-west reef, the reef flat is about 1300 m long and 300 m wide and drops gradually to a depth of 4 m. At extreme low tide a band of reef flat 60-200 m wide is exposed which consists mostly of dead coral, sand and seaweeds. In some places, especially near the fore and outer reef edges, there are small colonies of living coral. The outer reef edge is built up of dead coral and some living coral heads, with *Porites lutea* as the dominant species. Below 4 m the reef drops abruptly to approximately 20 m. The fore-reef edge consists of small colonies of living coral dominated by *P. nigrescens*. A total of 21 species of coral have been recorded from quadrats laid in depths of 1-6 m on the north-west reef. Living coral cover is 37.5% (Sumadhiharga, 1971).

The north-east-facing reef has a gently sloping reef flat extending 20-200 m off shore and to a depth of about 2 m. It consists of coral patches on white sand. Further seaward is a coral reef which is about 100 m broad and 2-6 m deep. This is followed by a sharp drop-off to a depth of about 20 m. About 200-250 m off shore, at a depth of approximately 3 m, *Tubipora musica, Stylophora mordax, Acropora tubicinaria* and soft corals occur. At 3-5 m depth, *Distichopora violacea, T. musica, Hydnophora rigida, A. tubicinaria, A. mauni* and *S. mordax* are common. Twenty-three species of coral were collected at this depth and living coral cover is 76%. A very strong rip current flows along the outer reef slope and living corals exist only sparsely, as small heads (Sumadhiharga, 1971).

The reef flat of the south-east reef is about 900 m long and 150 m wide and consists of dead coral, sand, rubble and a few small living corals restricted to pools and depressions that are covered by water at low tide. Beyond the reef flat is a gently sloping shelf with its outer margin about 300 m from the seaward edge of the reef flat. The first living corals encountered on this shelf, at a depth of about 4 m, are *T. musica, P. lutea, S. mordax, A. symmetrica, A. mauni* and *Goniopora malaccensis*. At a depth of about 4-6 m corals become more abundant, and living coral cover is 77.7%. Twenty-eight species have been collected in this zone and *P. lutea, P. nigrescens, G. malaccensis* and *T. musica* are especially common. The reef slopes steeply from a depth of 6 m, but no details of the slope fauna are available (Randall and Eldredge, 1983; Sumadhiharga, 1971).

On the south-west reef, the intertidal reef flat is about 400 m wide, and consists of white sand banks, shell grit and coral rubble. Beyond the reef flat is a gently sloping shelf extending about 200 m to the reef edge at a depth of 6 m. At a depth of 1-2 m, *P. nigrescens* and *A. symmetrica* are dominant, followed by a zone at 3 m characterized by *A. tubicinaria* and soft corals. Near the reef slope, at a depth of about 6 m, the dominant species are *G. tenuidens, Echinopora lamellosa* and *Millepora platyphylla*. A total of 24 species has been recorded on this shelf and living coral cover is 70%. The outer reef drops abruptly from a depth of 6 m to 20 m, but there are no details of coral fauna (Sumadhiharga, 1971).

The lagoonal reef slope from the south-west to the north is quite variable with respect to coral cover, sediments and steepness. In general the slope is steep where corals dominate and more gentle where sand and rubble dominate. Large individual coral colonies, up to 3 m in diameter and height, occur at some localities. In contrast to the diverse coral community found on the south-west lagoon slope, the same zone on the south-east slope is mostly devoid of corals. This is apparently an unstable habitat because of the accumulation of sand which is swept in from the adjacent reef platform (Randall and Eldredge, 1983).

A total of 105 species of corals from 53 genera and subgenera has been recorded from Pulau Pombo (UNDP/FAO, 1982f).

**Noteworthy Fauna and Flora** Turtles nest in low numbers on Pulau Pombo, and the island is a roosting site for the Pied Imperial Pigeon *Ducula bicolor*, and possibly for the megapode *Megapodius reinwardtii* (UNDP/FAO, 1982f). The breeding status of terns on the island is discussed in De Korte (1984).

Fifty-six species of molluscs, 17 species of echinoderms, 13 species of crabs and 130 species of fish are listed for the area by Sumadhiharga (1971). A later report (UNDP/FAO, 1982f) lists 142 species of molluscs. The bivalve *Septifer bilocularis* is often the dominant species on shallow, sandy reef flats (Sumadhiharga, 1971). Certain of the larger molluscs, notably the commercially valuable species, such as *Tridacna squamosa, Pinctada margaritifera* and *Pteria* spp. occur at Pulau Pombo but are uncommon. The commercial Trochus *Trochus niloticus* and the Horse's Hoof Clam *Hippopus hippopus* were also recorded (UNDP/FAO, 1982f).

**Scientific Importance and Research** The Lembaga Oseanologi Nasional (LON) has a marine research station on Ambon Island and as a result Pulau Pombo has been extensively surveyed (Kvalvagnaes and Halim, 1979c).

**Economic Value and Social Benefits** Pulau Pombo is uninhabited, but is used as an overnight base by fishermen. Fishermen operate with hook and line in deep waters near coral or rocky reefs, or with gill and seine nets in sheltered waters. Molluscs are collected from the reef flats and turtle and megapode eggs are dug up on the island. Tourism is apparently a growing industry and it is suggested that the greatest value of Pulau Pombo is for recreation, notably picnics, swimming and snorkelling/diving (marginal value) and also for reef research (UNDP/FAO, 1982f).

**Disturbance or Deficiencies** Sumadhiharga (1971) reported that parts of the reef were being damaged by explosives, the use of bamboo traps and collection of reef fauna. Further evidence of fisheries-related disturbances is included in Kvalvagnaes and Halim (1979c) and UNDP/FAO (1982f). About one-third of the reefs on Pulau Pombo are reported to have been destroyed by dynamiting (Kvalvagnaes and Halim, 1979c). Both PHPA and other boats are reported to be extremely careless when anchoring on reefs, as is evident by the many broken coral colonies. On the island itself, vegetation is cut, birds are hunted illegally and their eggs collected (UNDP/FAO, 1982f).

**Legal Protection** In 1973 Pulau Pombo was declared a Strict Nature Reserve and the surrounding reefs and sea a Marine Park. Fishing and collection of reef fauna is illegal, although permits may be issued allowing collection of living plants and invertebrates for scientific purposes (UNDP/FAO, 1982f).

**Management** PHPA has a Sub Balai office in Ambon and small rooms on Pulau Pombo. Pulau Pombo is supposed to be patrolled daily by a PHPA guard based in Wainuru, on Ambon, but it appears that visits are seldom made and patrols are ineffectual. Sign boards have been erected on the island, but have either been washed away or are overgrown (UNDP/FAO, 1982f).

**Recommendations** Pulau Pombo is readily accessible from Ambon and is valuable for research, education and particularly for recreation. It is recommended that the status of Pulau Pombo should be changed from Strict Nature Reserve (Cagar Alam) to Wildlife Reserve (Suaka Margasatwa) to enable its use for recreation. The Marine Park (Taman Laut) should be extended to include the atoll and surrounding waters to 1 km seaward of the reef flat, although the reefs are considered to have little conservation value at a national level (UNDP/FAO, 1982f).

It is recommended that a suitable PHPA presence should be established on the island so that management policies can be properly implemented. The reefs should be declared off limits for fishermen and it is suggested that four snorkelling/diving zones be established around specific mooring buoys, with a radius of 500 m. All other reef areas should be included in a wilderness zone where research and education could be carried out. Removal of coral, giant clam shells, sand, rock, turtles, turtle eggs and reef fauna should be prohibited, except for scientific specimens in the wilderness zone. An intensive use zone should be declared on part of the island and visitors should be restricted to this designated area (UNDP/FAO, 1982f).

Signboards should be erected and the PHPA should initiate a public relations programme so that their objectives and regulations become known to residents of nearby villages. It is suggested that owners of boats transporting people to the Marine Park should be held liable for infringements of general or specific regulations by their guests. It is recommended that the Marine Park is more effectively patrolled and that rangers, as well as the PHPA offices, should have a supply of information brochures. Permits to visit the area should be issued from the Sub Balai office in Ambon. Research should be encouraged in the Park and there must be constant monitoring of the effect of visitors on the reef at snorkelling/diving sites and on the islands, in order to determine whether damage is being done to corals or vegetation. Megapode and turtle nesting should also be monitored in order to determine population trends (UNDP/FAO, 1982f).

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## PULAU PENYU-PULAU LUCIPARA PROPOSED STRICT NATURE RESERVE

**Geographical Location** In the middle of the Banda Sea, about 200 km south of Ambon. 5°40'S, 127°50'E.

**Area, Depth, Altitude** 100 000 ha (Salm and Halim, 1984c).

**Physical Features** Pulau Pulau Maisel or the Lucipara Islands form an atoll consisting of four sand cays (Mai, Selatan, Laponda and Kaurangka) on a very exposed reef flat, bordered by narrow ramparts and with steep coral-covered seaward slopes (Borel-Best *et al.*, 1985).

**Reef Structure and Corals** The reef slope around the Lucipara Islands has over 50% coral cover. Richest coral growth is found at the drop-off where there are large branching *Acropora* colonies and massive Faviidae. The edge of the reef flat has abundant *Heliopora* and *Millepora*. The lagoon has rich coral growth dominated by branching *A. formosa* and *Heliopora sp.*. South of Mai, the reef is less varied and is dominated by *A. bruggemanni* (Borel-Best *et al.*, 1985).

**Noteworthy Fauna and Flora** There are nesting Green *Chelonia mydas* and Hawksbill *Eretmochelys imbricata* Turtles (Salm and Halim, 1984). Hundreds of Greater Crested Terns *Sterna bergii* occur on Selatan, the easternmost of the four islands (De Korte, 1984). The Coconut Crab *Birgus latro* may occur (Usher, 1984).

**Scientific Importance and Research** Visited by the Snellius-II Expedition (Borel-Best *et al.*, 1985).

**Economic Value and Social Benefits** There are a few temporary inhabitants who live mainly by fishing and catching turtles (Borel-Best *et al.*, 1985) and the area is important for the collection of reef invertebrates (Usher, 1984).

**Disturbance or Deficiencies** The reef is reported to be in exceptionally good condition (Borel-Best *et al.*, 1985). There has been intensive turtle harvesting and collecting of tern eggs (De Korte, 1984).

**Legal Protection** None.

**Management** None.

**Recommendations** A proposal has been made to establish a strict nature reserve around the islands, and the area is listed in Salm and Halim (1984a) as one of "First Order Priority".

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## TELUK AMBON PROPOSED MARINE MULTIPLE-USE RESERVE

**Geographical Location** South-west Ambon; 3°40'S, 128°10'E.

**Area, Depth, Altitude** 50 000 ha; coral development below 15 m is minimal (McManus and Wenno, 1981).

**Physical Features** Ambon Bay is elongate, along a north-east to south-west axis, and nearly divides the island of Ambon. The outer bay is connected to a small inner bay by a channel less than 1 km wide and 15 m deep. The outer bay exceeds 250 m in depth near Ambon City, and 700 m near the mouth. It is bounded on all sides by a shallow-water shelf (3-10 m deep), generally less than 200 m wide, where corals grow. Coral communities are scattered, and development is greatest along the north-westerly-facing coastal shelf (McManus and Wenno, 1981).

The bay is subjected to a southerly monsoon from May to October and a northerly monsoon from December to March. Although squalls are common within the bay, the orientation of the land affords some protection from the monsoons. Rainfall is heaviest from May to August and varies during the year from approximately 11 cm to over 603 cm a month. Many rivers and streams drain into the bay from the surrounding hills (McManus and Wenno, 1981).

**Reef Structure and Corals** Coral communities in outer Ambon Bay have been studied by Borel-Best *et al.* (1985), McManus and Wenno (1981), Randall and Eldredge (1983) and Wattimury *et al.* (1981). McManus and Wenno (1981) found a range of coral communities along the shallow coastal shelf, with maximum development along the outer edge of the shelf. The regions of hard coral dominance were grouped into four classes based on decreasing hard coral development. Class 1 was characterized by patches of apparent high species/area diversity, mixed with a few monospecific stands. In places, hard coral cover exceeded 75%. Zones dominated by tabular *Acropora* were clearly defined, as were monospecific stands of branching *Acropora*, foliose *Montipora* and *Galaxea*. Class 2 was characterized by a predominance of monospecific coral stands, associated with coral aggregations of moderate species diversity. Coral communities were interrupted by patches and channels of silty sand. North of Laha, towards the inner part of the north coast of the bay, stands of *Goniopora* and *Euphyllia* covered areas of 50-200 sq. m. Mounds of *Galaxea* and *Porites* longer than 10 m and higher than 3 m were found. Stands of branching *Acropora* and foliose forms of *Montipora, Echinopora, Mycedium* and others formed large monospecific patches of varying sizes. South of Laha, towards the entrance of the bay, long stands of branching *Acropora* were common, as were fields of *Lobophyllia* more than 20 m across.

Regions in Class 3 contained a heterogeneous range of hard coral communities, most of which were divided into low patches by sand and gravel or clumps of alcyonaceans. Species/area diversity was moderate to high in most patches. The Ambon Coral Gardens fall into this category. Regions in Class 4 contained small and infrequent patches of corals. *Seriatopora, Stylophora, Pocillopora, Acropora, Tubastrea* and *Distichopora* were found, together with some small (less than 1.5 m diameter) *Porites* heads. Some areas were characterized by various fungiid accumulations, corals growing on stone boulder substrates and small patches of diverse coral aggregations separated by large sandy areas (McManus and Wenno, 1981).

Randall and Eldredge (1983) reported a reasonably high species diversity, but noted that colonies were usually small. Borel-Best *et al.* (1985) found that only sediment-tolerant species and genera were common, such as *Goniopora, Symphyllia, Fungia actiniformis, Pterogyra sinuosa* and *Euphyllia glabrescens*. *Porites* still formed large colonies up to 1 m in diameter, but other species formed only small colonies, larger colonies being dead, particularly on their horizontal surfaces.

**Noteworthy Fauna and Flora** The majority of fish observed along the shallow-water shelf of the bay were associated with coral communities and included food fish such as lutjanids, serranids, carangids and acanthurids. Black-tip sharks were relatively common, and white-tip sharks seen occasionally (McManus and Wenno, 1981). The brachyuran fauna is described by Serene (1971). There are some mangroves (Salm and Halim, 1984c).

**Scientific Importance and Research** Ambon Bay has been the site of considerable taxonomic work (McManus and Wenno, 1981), and work is continuing under programmes of the Lembaga Oseanologi Nasional, Lembaga Limu Pengetahuan Indonesia, and Pattimura University, in co-operation with the University of Washington and the U.S. Agency for International Development (McManus and Wenno, 1981). Ambon was visited by the Snellius II Expedition (Borel-Best *et al.*, 1985)

**Economic Value and Social Benefits** A major industry of Ambon city is offshore skipjack tunafishing. Most baitfish (*Stolephorus*) for this industry are captured within the bay. Small fishing villages are scattered along the coastline of Ambon Bay and artisanal fishermen operate throughout the area (McManus and Wenno, 1981). Ornamental fish are collected for the aquarium trade.

**Disturbance or Deficiencies** There is evidence to suggest that fish stocks are being overexploited. Fishermen have reported a recent decline in available baitfish for the tuna industry, and the population of artisanal fishermen has greatly increased in recent years, thereby increasing pressure on food species. Local fishermen are causing considerable damage to corals. Traps are dragged across coral communities, corals are damaged by anchors, and colonies are broken off to disguise fish traps or to catch the small fish that hide inside them (McManus and Wenno, 1981).

Many coral colonies show signs of recent sediment encroachment, especially along the northern shore, east of Laha. It is not known whether this is due to natural changes in sedimentation processes or is related to recent deforestation. Most of the refuse from the fishing villages is deposited directly into the sea, including a wide array of materials, especially organic wastes, plastic containers, rags, cans, bottles and soap. Future problems from increased siltation and pollution related to urbanization are anticipated (Borel-Best *et al.*, 1985; Burbridge and Maragos, 1985; Djuhari, 1982; McManus and Wenno, 1981).

**Legal Protection** None.

**Management** No information.

**Recommendations** A proposal has been made to establish a marine multiple-use reserve in Ambon Bay (Salm and Halim, 1984c), and the area is listed in Salm and Halim (1984a) as a "Third Order Priority Area". Djuhari (1982) stresses the need for conservation education in the Ambon Bay area.

# IRIAN JAYA

## PULAU MAPIA PROPOSED WILDLIFE RESERVE

**Geographical Location** About 180 km north of Manokwari on the northern coast of Irian Jaya; 1°10'N, 134°10'E.

**Area, Depth, Altitude** 1557 ha (Soegiarto *et al.*, 1982); 3760 ha (Usher, 1984); or 11 000 ha (Salm and Halim, 1984c).

**Physical Features** An atoll, with associated coral islands and reefs (Salm and Halim, 1984a and c).

**Noteworthy Fauna and Flora** The islands are nesting sites for the Green Turtle *Chelonia mydas* and the Hawksbill *Eretmochelys imbricata*. The Coconut Crab *Birgus latro* also occurs here (Salm and Halim, 1984a and c). There is a large population of the Giant Clam *Tridacna derasa* as well as other giant clam species. Trochus *Trochus niloticus* is abundant (Usher, 1984).

**Economic Value and Social Benefits** There is small-scale exploitation of reef invertebrates by the small local population (Usher, 1984).

**Disturbance or Deficiencies** Increased collection of reef invertebrates is a potential threat (Usher, 1984).

**Legal Protection** None.

**Management** No information.

**Recommendations** A proposal has been made to establish the atoll as a wildlife reserve, and it is listed in Salm and Halim (1984a) as a "First Order Priority Area". It is a high priority for reef invertebrate conservation and Usher (1984) recommends that the uninhabited northern islands, Fanildo, should be declared a sanctuary zone for *Birgus latro* and that the rest of the atoll should be managed as a traditional use zone. However, the remoteness of the atoll will hamper management.

## RAJA AMPAT PROPOSED WILDLIFE RESERVE

**Geographical Location** Off the extreme north-west tip of Irian Jaya; 0°25'S, 130°08'-57'E.

**Area, Depth, Altitude** 2976 ha (Soegiarto *et al.*, 1984); 50 000 ha (Salm and Halim, 1984c).

**Physical Features** The area includes a number of islands, the largest being Waigeo. Terrestrial features of these and adjacent islands are described in Diamond (1986).

**Reef Structure and Corals** No information.

**Noteworthy Fauna and Flora** There is extensive mangrove forest on the coast (Diamond, 1986). The islands are nesting sites for the Green Turtle *Chelonia mydas* and the Hawksbill *Eretmochelys imbricata* (Salm and Halim, 1984). They are extremely important for their avifauna with five endemic species and more than 20 endemic subspecies. Details of the terrestrial fauna are given in Diamond (1986). The terrestrial reserve at Pulau Waigeo is described in IUCN (in prep.).

**Scientific Importance and Research** No information.

**Economic Value and Social Benefits** There are permanent villages on the larger islands and on some of the adjacent smaller ones but Kawe and Doif are uninhabited. All villages are located on the coast and fishing is a major activity both for subsistence and for the export of dried fish, turtle shell and dried shark's fins (Diamond, 1986).

**Disturbance or Deficiencies** Logging on these islands has almost ceased so there is unlikely to be a major threat from siltation. Marine turtles and sharks are harvested in large numbers on the south coast of Misool, and marine resources in general may be being overfished (Diamond, 1986).

**Legal Protection** Pulau Waigeo Barat was established as a Strict Nature Reserve in 1981 but does not include reefs (IUCN, in prep.).

**Management** No information.

**Recommendations** There is urgent need for a survey of the status of marine resources and colonial islet birds (Diamond, 1986). A proposal has been made to establish the Raja Ampat area off Pulau Waigeo as a Wildlife Reserve (Salm and Halim, 1984c); it is listed in Salm and Halim (1984a) as a "First Order Priority Area". A seaward extension to the Pulau Waigeo reserve is also recommended as a Third Order Priority.

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## TELUK CENDERAWASIH-KEPULAUAN AURI PROPOSED WILDLIFE RESERVE

**Geographical Location** The proposed reserve is on the south-west side of Cenderawasih Bay, on the north coast of Irian Jaya, and includes Pulau Anggremeos; 1°43'-3°22'S, 134°06'-135°10'E.

**Area, Depth, Altitude** The total area of the proposed reserve has not been specified, but 600 000-700 000 ha are being considered (Gilkes *in litt.*, 26.2.87). Reefs extend from sea-level to more than 40 m, although many are 20 m or less in depth; they cover an area of about 80 000 ha.

**Physical Features** The mainland coastline is steep and the 200 m depth contour lies relatively close inshore. The reefs and islands of the Auri archipelago lie on the edge of the continental shelf and form a distinct submarine plateau, especially at the northern end. There are five major reef forms (patch, fringing, barrier, atoll and shallow water reef mounds) with several variations of each in the proposed reserve (UNDP/FAO, 1982a). There are over 40 patch reefs, some with a cay, others with a lagoon or semi-enclosed bay, in a chain that extends from the southern shore of the reserve. The barrier reef lies along the edge of the continental shelf at the southern end of the bay. Fringing reefs surround the four large continental islands (Rumberpon, Maswaar (Mios Waar), Room, Anggremeos) which lie off the west coast of Teluk Cenderawasih. They also occur around the islands at the northern end of the archipelago, and along much of the west coast of the bay itself. A small atoll, with a rim of coral surrounding a deep lagoon, lies in the central part of the archipelago, at its eastern edge. Shallow water reefs, mounds and ridges are found on the submarine plateau which marks the northern limit of the archipelago.

**Reef Structure and Corals** Detailed information on the reefs and corals is not available. The preliminary survey (UNDP/FAO, 1982a) reported that the seaward margins of sea-level patch reefs are generally sheer, and drop from the crest at 1 m to the first ledge at 20-40 m depth. These vertical fore-reefs are studded with corals, sponges, seafans and many other invertebrates; reef fish are abundant and large. Sub-sea-level patch reefs have a variable gradient fore reef. Fringing reefs have a gentle gradient in bays and sheltered areas but are steeper elsewhere. A sheltered reef in a semi-enclosed bay at Pulau Papaya was found to be of unique interest. It is a porous, loosely consolidated reef of branching *Porites andrewsi* in the upper reaches, which may form great turrets, and whorls of *Pachyseris* and *Echinopora lamellosa* down the slopes. There are vertical cliffs with deep caves and tunnels, fretted with holes. Reef flats are formed of talus sand, colonized in places by seagrasses and algae, and on larger sea-level or submerged patch reefs frequently have pools (1-2 m depth) or lagoons (20 m depth or more) which offer sheltered habitats for coral growth. Coral diversity was generally high; a total of 62 genera and 130 species was recorded during brief searches at 27 sites.

**Noteworthy Fauna and Flora** Giant Clams *Tridacna gigas, T. squamosa, T. crocea*, Horse's Hoof Clams *Hippopus hippopus*, commercial trochus *Trochus niloticus* and pearl oyster shells *Pinctada margaritifera* are relatively abundant. The only confirmed large populations of *T. gigas* remaining in Indonesia are found here (Usher, 1984). Green Turtles *Chelonia mydas* and Hawksbills *Eretmochelys imbricata* feed and nest in the Auri archipelago. Dugongs *Dugong dugon* occur along the west coast of Teluk Cenderawasih and around certain islands. The Saltwater Crocodile *Crocodylus porosus* survives on the northern islands of the archipelago. Commercially valuable fish such as lethrinids, lutjanids, serranids, carangids and barracudas, and reef/shoal associated genera, such as *Scomberomorus, Katsuwonsus* and *Euthynnus*, are common. The UNDP/FAO survey report emphasizes that it is uncommon to find such an abundance and complete representation of these species on the heavily-exploited reefs of Indonesia. On certain islands in the archipelago there are good examples of strand and cay vegetation, which apparently are rarely found elsewhere (UNDP/FAO, 1982a). Many of the islets are important for nesting seabirds (IUCN, in prep.). Mangroves are found in a number of areas (Gilkes and Adipati, 1986).

**Scientific Importance and Research** Little work has been carried out on the reefs in the proposed reserve but the survey, undertaken as part of the UNDP/FAO National Parks Development Project, indicated a high diversity of corals and other reef and reef-associated fauna, in a relatively undisturbed condition. Currently survey work is being carried out as part of WWF/IUCN Project No. 1528 (Gilkes and Adipati, 1986).

**Economic Value and Social Benefits** The islands of the archipelago are not permanently inhabited, but the reefs are visited by migrant fishermen who camp there for several months at a time. They subsist on fish, turtles, turtle eggs and molluscs which they harvest locally, supplemented occasionally by Dugongs and crocodiles. In addition, they smoke or salt fish and store it for future use. The reefs of the archipelago provide feeding and nursery areas for many commercial fish species which at present are not heavily fished. The Butungese people have already discovered the richness of the mollusc resources in the archipelago, and periodically sail there (a distance of more than 15 000 km) to collect shells, particularly of *Trochus niloticus*. The value for tourism, particularly of the southern reefs, would be high if they were more accessible, but they currently have greater value for reef ecosystem conservation at the national level than for tourism development at the provincial level (UNDP/FAO, 1982a).

**Disturbance or Deficiencies** The Crown-of-Thorns Starfish *Acanthaster planci* was reported to be destroying entire coral reefs in the area in the early 1980s (UNDP/FAO, 1982a) but recently numbers have declined dramatically (Gilkes *in litt.*, 26.2.87). The condition of reefs in the Teluk Wandaman (Kecamatans Wasior and Windesi) area is generally good with a high species diversity but there is concern about the species used commercially by local villagers and migrant fishermen who collect nesting turtles and their eggs, spearfish adult turtles and large reef fish, fish with dynamite over shallow reefs and collect giant clams. Dynamite fishing has occurred in many areas of the proposed reserve but is now only carried out by outside fishermen in the more isolated and uninhabited Auri Archipelago (Gilkes *in litt.*, 26.2.87). The Butungese collect *Trochus* and *Pinctada* shells (Usher, 1984). Coral collecting takes place on a very small scale for building materials but most constructions are of wood or concrete (Gilkes *in litt.*, 26.2.87). Many marine resources have been severely depleted since the beginning of the 1980s (UNDP/FAO, 1982a; Gilkes and Adipati, 1986). A large fishing facility is being constructed on Biak and ships from there have already started operating in the area of the reserve (Usher, 1984).

**Legal Protection** Pulau Anggremeos, at the southern end of the archipelago, was declared a Wildlife Reserve in 1981.

**Management** No information.

**Recommendations** This is considered one of the highest priority areas for protection in Indonesia (Salm and Halim, 1984a and c) and is a high priority for reef invertebrate conservation (Usher, 1984). The proposed area is to include the Pulau Anggremeos Wildlife Reserve and will be administered from here (IUCN, in prep.). The remainder of the reserve will cover part of the mainland and its reef-fringed coast and incorporate a number of other islands. A management plan is being prepared as part of a WWF/IUCN project. There is urgent need for improved cooperation between PHPA and the Fisheries Departments to avoid confusion over their responsibilities for different resources. A PHPA guard post should be established on Pulau Anggremeos to patrol the uninhabited Kepulauan Auri Island Chain, the upper islands of which are the priority area for the marine reserve. The Gereja Kristen Injili (GKI) Church has assisted with the development of the management plan and, as the dominant social force in the coastal villages of the reserve area, has a closer relationship with the local people than Forestry or PHPA. UNDP may have some involvement in the development of the reserve as part of their Regional Planning Programme for Irian Jaya. One of the areas recommended for the location of such a development project involves the western section of Suaka Margasatwa Teluk Cenderawasih. Field work is continuing under the WWF/IUCN project around the islands of Rumberpon, Mios Waar and Roon and the areas of coastline in Kecamatans Wasior and Ransiki that have not yet been visited (Gilkes and Adipati, 1986). A project concept for continued work on the management of this area is currently being prepared by IUCN (McNeely *et al.*, 1986).

# IRAN

## INTRODUCTION

### General Description

Iran has over 2000 km of coastline in its southern region, about two thirds of which faces the Gulf with the remainder lying east of the Strait of Hormuz in the Gulf of Oman. Little information is available on the marine environment apart from papers by Harrington (1976), Marini (1985) and some early Danish work (Jessen and Sparck, 1939-1949) although there are numerous publications on fishery-related issues which are cited in Marini (1985). In the early 1970s, a marine laboratory had been established at Bandar Abbas, a marine research station was being built on nearby Hormoz Island and aerial surveys of the entire coastline were being carried out. The coastal zone is predominantly limestone with some shales and salt domes. Annual rainfall in the coastal region ranges from 100 to 300 mm, mostly falling between November and April. Temperatures reach 45°C in summer and fall to 5-10°C in the winter.

Harrington (1976) divides the coast into ten segments and describes the features of each in some detail. The western half of the coastline contains estuarine conditions, sand dunes, extensive tidal flats and mangroves, with an area of cliffs near the Strait of Hormuz. The easternmost part of the Gulf coast has eight offshore islands which extend from Asaluyeh (Bandar Asalu) east to Bandar Abbas in the Strait: Qeshm, Hormoz, Larak, Hengam, Forur, Kish, Hendorabi and Lavan (Sheyk Sho'eyb). All are rocky and sparsely populated and the easternmost are surrounded by substantial coral reefs, although no patch or barrier-like systems have been reported. A detailed description of Hormoz is given in Marini (1985) and the reefs are described by Harger (1984). Nineteen coral species were recorded and the best reef development was found on the south-eastern margin of the island. In the Gulf of Oman, offshore depths increase to over 50 m and the coastline has extensive sand dunes, sandy beaches and areas of cliffs. Where the sublittoral has hard substrate, corals and reefs reappear. The large bays at Chah Bahar and Pozm (Pizom) in south-eastern Baluchestan are two of the finest bays along Iran's south coast and lie in a region with an extremely rich and diverse marine fauna. Chah Bahar has important seagrass beds, beautiful coral, averages about 6 m in depth and normally has good visibility.

Green Turtles *Chelonia mydas* nest in small numbers at Bushehr (Bandar Bushr) and Ras Beris; Hawksbill Turtles *Eretmochelys imbricata* occur in significant numbers in the area from Taheri (Siraf) to Bandar-e-Lengeh, at Qeshm Island and from Tang (Bandar Tang) to the Pakistan border (Groombridge, 1982; Ross and Barwani, 1981) but this information is based on a brief survey of Iran over a decade ago and new data are urgently required (Groombridge pers. comm., 1985). There are an estimated 8900 ha of *Avicennia* mangrove along the Iranian coast. The westernmost stand at Asaluyeh has been badly cut and is rapidly disappearing. The largest stand (6800 ha) is in the Khowran (Khoran) Straits and is included within the 82 000 ha Hara Protected Region. Harrington (1976) gives a more detailed description of mangrove distribution. Gallagher *et al.* (1984) detail the breeding seabird species of Iran. The Iranian National Centre for Marine Science is responsible for marine research (IUCN/UNEP, 1985).

### Reef Resources

There is a large artisanal fishery in Iran but this is largely based on pelagic, rather than reef species (Morgan, 1985). There is no information on the recreational use of reefs, but this is probably unimportant.

### Disturbances and Deficiencies

Harrington (1976) reported very little oil pollution in the mid-1970s, with the exception of localized concentrations. The amount of non-degradable litter, however, appeared to be disproportionately great. Reza (1985) describes the effects of the oil spill from the Nowruz oil fields north-west of Kharg Island in the north of the Gulf; these are situated beyond the area of reef development but it is not clear whether pollution was carried to reef areas.

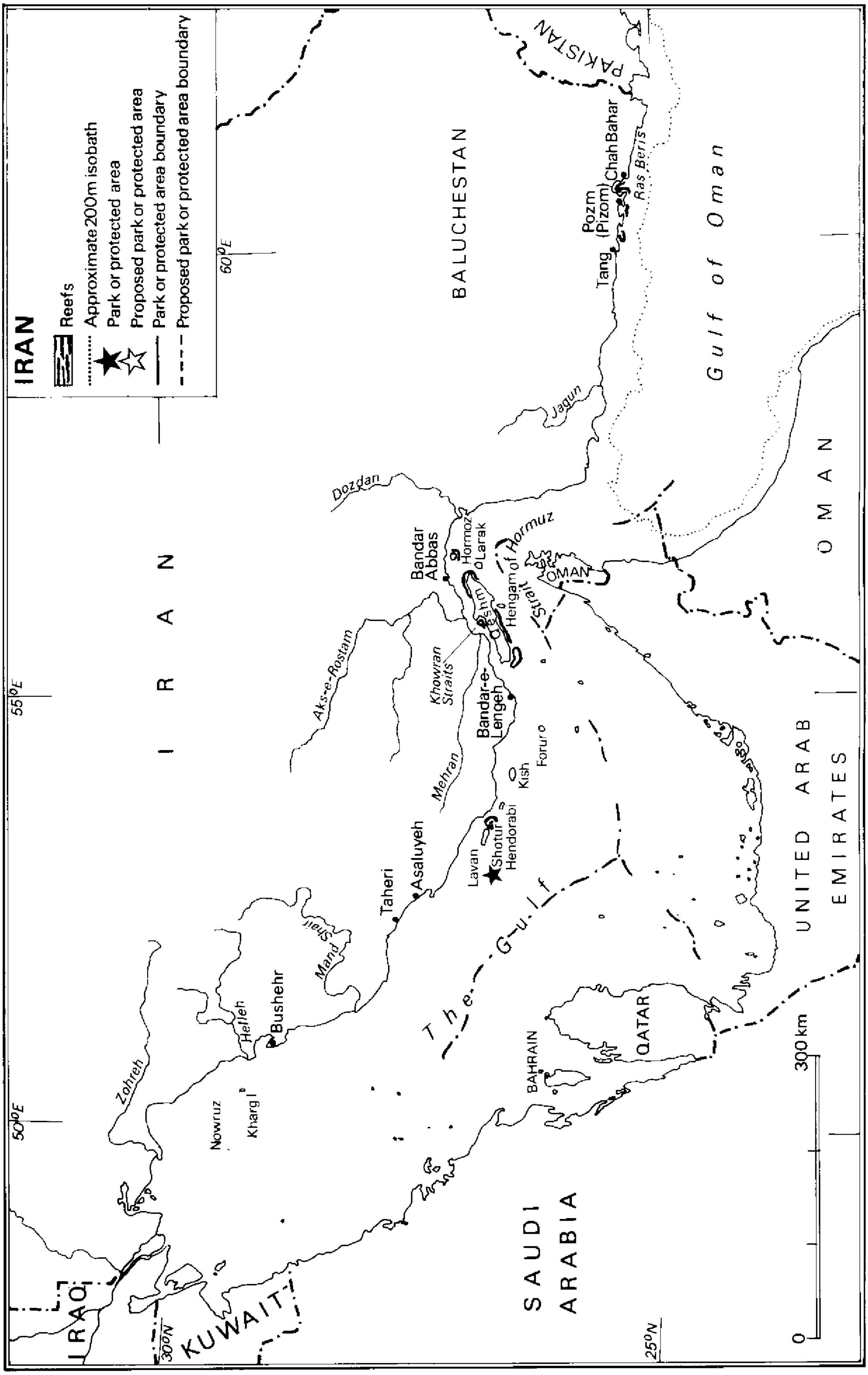
### Legislation and Management

Iran has ratified the Regional Convention for Co-operation on the Protection of the Marine Environment from Pollution (IMO/ROPME/UNEP, 1984). The Department of the Environment has recently presented details of its policies regarding marine discharges and permissible levels (Keyvani, 1984). The organisational structure of the government with regard to marine and environmental monitoring is also given. The main law covering conservation within Iran is the Environmental Protection and Enhancement Act of 1974 (IUCN/UNEP, 1985). Early descriptions of environmental management and protection are given in Firouz (1976) and Firouz *et al.* (1970). Shotur (Sheedvar) Island Reserve (*see separate account*) is the only existing protected area to include reefs.

### Recommendations

Harrington (1976) discussed the need for management of marine resources and the lack of base line information, although the then Department of the Environment was placing a high priority on these issues. A number of proposed marine reserves are listed in Harrington (1976). The following include coral reefs:

- Hormoz Island
- Chah Bahar - proposed for protection by the Tourist-Consult group in the 1970s as it is one of the few sites on the coast line suitable for SCUBA diving. Due to the presence of a great deal of coastal development, including a large military installation it is probably not suitable for National Park status.


IRAN
Reefs
Approximate 200m isobath
Park or protected area
Proposed park or protected area
Park or protected area boundary
Proposed park or protected area boundary
PAKISTAN
BALUCHESTAN
Chah Bahar
Ras Beris
Pozm
(Pizom)
Tang
Gulf of Oman
Jagun
Dozdan
Bandar
Abbas
Hormoz
Larak
Strait of Hormuz
Qeshm
Hengam
OMAN
Khowran
Straits
Aks-e-Rostam
Bandar-e-
Lengeh
Foruro
Kish
Mehran
Asaluyeh
Taheri
Lavan
Shotur
Hendorabi
Mand
Bushehr
Helleh
Zohreh
Nowruz
Kharg I
The Gulf
I R A N
BAHRAIN
QATAR
UNITED ARAB
EMIRATES
O M A N
SAUDI
ARABIA
KUWAIT
IRAQ
60°E
55°E
50°E
30°N
25°N
0
300km

- Pozm Bay - a smaller similar bay, relatively free from development.

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## SHOTUR (SHEEDVAR) ISLAND RESERVE

**Geographical Location** Off the eastern end of Lavan Island (Sheyk Sho'eyb) in the Gulf; 26°47'N, 53°25'E.

**Area, Depth, Altitude** 160 ha.

**Physical Features** No information.

**Reef Structure and Corals** Shotur (Shetvar, Sheedvar) Island is reported to be surrounded by excellent coral reefs (Harrington, 1976).

**Noteworthy Fauna and Flora** Groombridge (1982) reports that the island may be the major nesting site in Iran (up to 500 nests in 1971) for the Hawksbill Turtle *Eretmochelys imbricata*. Gallagher *et al.* (1984) describe the population and status of breeding seabirds which include *Sterna bergii, S. bengalensis, S. repressa* and *S. anaethetus*. There was an estimated population of 500 000 breeding terns in the early 1970s (Harrington, 1976).

**Scientific Importance and Research** No information.

**Economic Value and Social Benefits** No information.

**Disturbance or Deficiencies** No information.

**Legal Protection** Fully protected since 1972 (Harrington, 1976).

**Management** No information.

# ISRAEL

## INTRODUCTION

### General Description

Israel has a very short coastline in the far north of the Gulf of Eilat (Aqaba), which, in this area, consists of a narrow but long and deep volume of water. North of Di Zahav, depths reach 1800 m while 35 km south of Eilat, depths are 1000 m, the shoreline sloping very steeply to these depths. Rainfall is very low (about 22 mm a year) and evaporation exceeds 2000 mm a year, resulting in an elevated salinity of about 42 ppt (Loya and Slobodkin, 1971). Water temperature and salinity fluctuate slightly throughout the year. Winds blow predominantly from the north or north-east and cause a general counter-clockwise circulation in the northern part of the Gulf of Aqaba with a mainly southerly flow of surface water along the Israeli coast. However, current vary seasonally (Klinker *et al.*, 1978). The winds also cause a southwards transport of sand into the Gulf which, together with discharges from wadis following occasional rains, cause accumulations of sand on flat areas of the coast. Tides are small, with occasional important very low tides which expose the reef flat. These low tides usually occur in summer but abnormally low tides were recorded in March 1983 when the sea-level dropped 30-50 cm below the reef flat.

Most of the coastline has reefs, either fringing or in the form of large offshore knolls, except in areas of major port construction. Eilat lies in the north-western corner of the Gulf, where the sea bottom is mainly sandy with a few coral patches. Coral knolls and patches are found in increasing density south of Eilat, particularly 8-9 km south where a diverse reef is found, which is protected as the Eilat Coral Reserve (*see separate account*). The reef 5 km south of the Reserve is free from much man made perturbation (Loya, 1976a). The reefs along the southern beach take the form of large knolls. The fore-reef (2-3 m wide) is followed by a shallow slope of sand with large patches of seaweed *Halophyla stipulacea* and several populations of garden eels (Heterocongrinae) (Shlesinger *in litt.*, 29.2.84). Cohen (1975) gives a brief description of the reefs at Taba on the border. Loya and Slobodkin (1971) list 99 scleractinian corals in 40 genera for the area. The fringing reefs are dominated by stony corals, although within the lagoon and on the reef flat, brown algae are abundant. Recently coral bioherms have been discovered between 120 and 200 m, formed mostly by *Madracis interjecta* and sometimes by *Dendrophyllia minuscula* (Fricke and Hottinger, 1983).

The short coastline of Israel has been more extensively studied than any other area of the Gulf of Aqaba. Most research is carried out in the Reserve (*see separate account*). Studies on mariculture, coral reef ecology, marine microbiology and productivity, parasitology and fish behaviour are carried out at the Heinz Steinitz Marine Biological Laboratory 300 m to the south of the Reserve. Mariculture is an important aspect of the Eilat branch of the Oceanographic and Limnological Company of Haifa. Much scientific research in the Sinai Peninsula was initiated from Israel, particularly studies on corals, echinoderms, coral reef fish and the effects of pollution on coral reef communities (Fishelson 1971 and 1977; Loya 1975, 1976a, 1976b and 1976c; Loya and Rinkevich 1979 and 1980; Mergner 1971; Safriel *et al.*, 1980; Schuhmacher 1973 and 1975). Scientists from Jordan's research centres also visit the coastline.

### Reef Resources

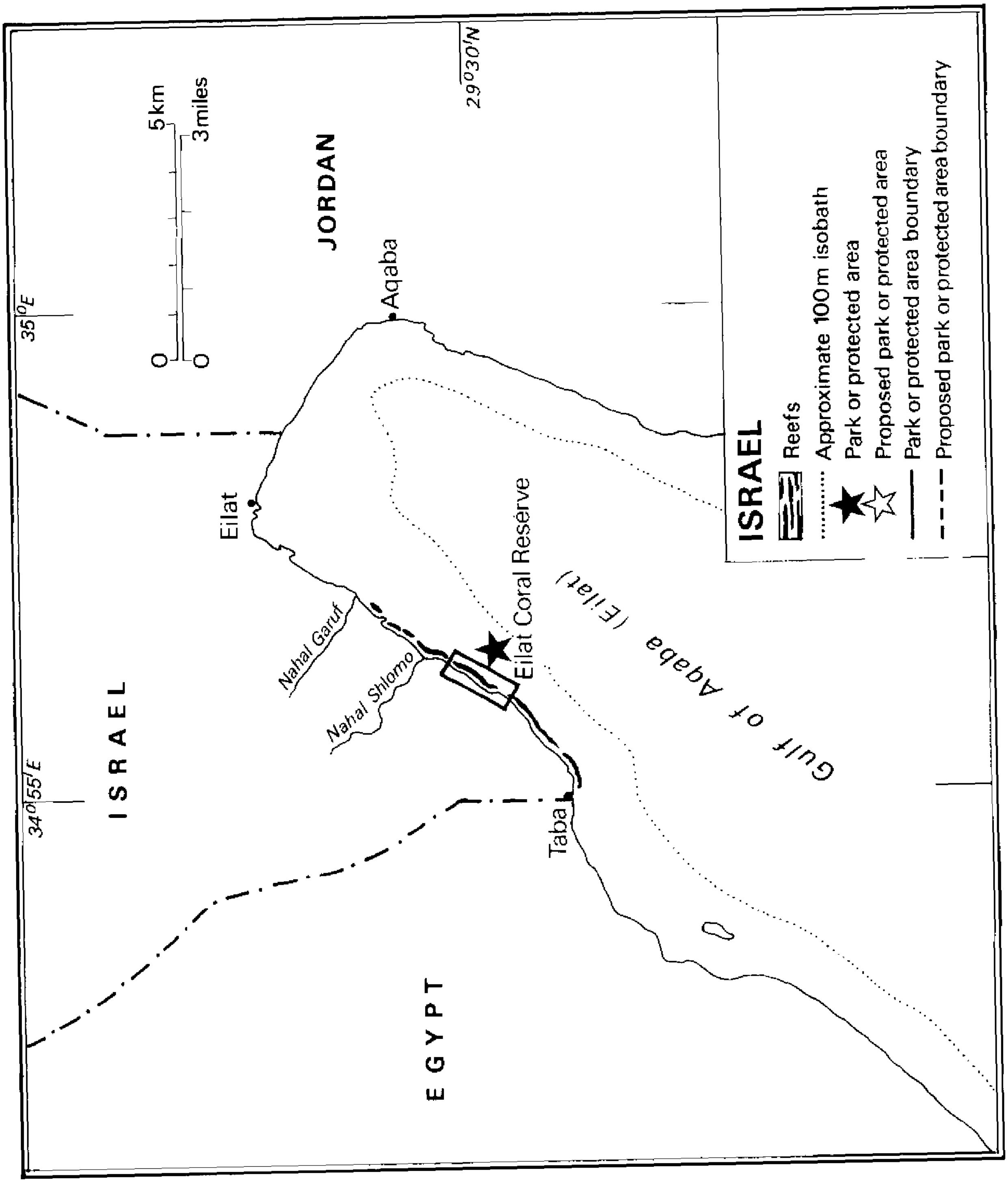
Tourism is of major importance. The north beach close to Eilat has an artificial lagoon with a well-developed marina. There are 15 hotels in this area with comprehensive facilities for marine and reef-related activities. A second tourist area is based north of the coral reserve, 8 km south of Eilat and there are now major developments along the southern shore including hotels and diving facilities. The Coral World Aquarium and Observatory is situated on the edge of the Reserve and was opened in 1975. Sharks, turtles and a wide variety of fish are on display and there is a museum. An underwater observatory is situated 100 m off shore, 4.5 m below sea-level, and itself forms an artificial reef and has particularly abundant life around it.

### Disturbances and Deficiencies

Abnormally low tides in September 1970 and March 1983 caused extensive mortality of branching corals (Loya, 1976a; Schlesinger *in litt.*, 18.3.85). The rapid development of Eilat represents a considerable threat to the reefs (Clark and Vanderbilt, 1982) (*and see separate account for* Eilat Coral Reserve). A shortage of sandy beaches could lead to a massive tourist development along the southern part of the coast which could affect the reefs. There is also a potential threat from pollution from crude oil and phosphate due to the industrial facilities to the north near Eilat.

### Legislation and Management

The Nature Reserves Authority has been extremely active in promoting reef conservation (*see separate account for* Eilat Coral Reserve). The Society for the Protection of Nature has field schools, including one at Eilat, which provide public education on environmental issues (Clark and Vanderbilt, 1982). Numerous pubications on marine life have been produced for visitors including underwater fish guides (Cohen, 1978) and divers guides (Cohen, 1975). The International Convention for the Prevention of Pollution is enforced. The marine pollution section of the Environmental Protection Service (EPS) has far reaching authority in law enforcement, treatment and prevention of environmental damage and surveys and research. Marine inspectors in Eilat are on constant alert for pollution episodes, and an Eilat Pollution Control Station is being set up (Anon., 1983). Efforts are being made to ensure that environmental matters are taken into consideration in the development of tourism.


ISRAEL
Reefs
Approximate 100m isobath
Park or protected area
Proposed park or protected area
Park or protected area boundary
Proposed park or protected area boundary
0 5km
0 3miles
JORDAN
Aqaba
Eilat
Eilat Coral Reserve
Gulf of Aqaba (Eilat)
Nahal Garuf
Nahal Shlomo
ISRAEL
Taba
EGYPT
35°E
34°55'E
29°30'N

### Recommendations

The reef along the southern beach is "public" but is under the protection of the Nature Reserves Authority and the Eilat Municipality. It is recommended that the beach remain open to the public but that development be limited to areas west of the main road only. The area east of the road encompasses a beach-front tract of about 50 m width. This area should be a buffer zone between the coral reserve and the southern parts of the Gulf. A detailed monitoring programme has been carried out in this area in order to ensure development without damage (Shlesinger *in litt.*, 29.2.84).

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**EILAT CORAL RESERVE**

**Geographical Location** North-western part of the Gulf of Eilat, 10 km south of the town of Eilat (UTM: 2662/6866); 29°30'N, 34°55'E.

**Area, Depth, Altitude** Surface area 50 000 sq. m (12.5 acres; 5 ha). 1.2 km in length, extending 400 m seaward. Reef table is 1 m below sea-level; base of reef wall is at 5-8 m depth.

**Land Tenure** Nature Reserves Authority, apart from the observatory which is privately owned.

**Physical Features** The tidal area consists of beach-rock and small sandy patches. The narrow (10-20 m wide) lagoon has a granite floor covered with pebbles and scattered small coral colonies and a maximum depth of 2 m (Loya and Slobodkin, 1971). A continuous fringing reef runs the length of the Reserve. In the north, the fore-reef drops to 5 m, and a sandy terrace with scattered coral knolls extends to 12-15 m depth. To the south, and covering 70% of the area, the fore-reef drops to 8 m and the terrace is covered with corals and small mounds to 15 m depth. The sea bottom drops off steeply from 15 to 35-40 m and is followed by a gently sloping terrace to 60-70 m depth.

Salinities range from 41 ppt to 42 ppt; water temperature is 22-28°C, and visibility is exceptionally clear even in deep water. The sea is generally calm with small waves produced by northerly winds. In autumn and spring, occasional southerly storms increase wave action causing turbidity which lasts several days. The seawater is generally poor in nutrients, although upwelling in the winter results in seasonal blooms of plankton.

**Reef Structure and Corals** Loya and Slobodkin (1971) describe reef profiles at 84 line transects. Although different zones have been identified, these are not always clearly defined. The dominant coral in the lagoon is *Stylophora pistillata*; other typical but less abundant species are *Cyphastrea microphthalma, Millepora platyphylla, M. dichotoma, Platygyra lamellina* and *Favia favus. Seriatopora caliendrum* forms very dense patches in the central part of the Reserve. Coral cover averages 36% but decreases with depth. Other invertebrates including sea anemones *Radianthus oseirensis* are found in this zone.

The rear reef of the reef crest region is dominated by *S. pistillata*, making up about 22% of living corals. *C. microphthalma* is the second most abundant species (13%) and *M. dichotoma* and *M. platyphylla* also play important roles. The reef flat is dominated by *S. pistillata* (25%) with *C. microphthalma* and *F. favus* covering 12.5% each. The outer wall of the reef flat (1-3 m) is dominated by *M. dichotoma* (36%) and represents a spur and groove system which makes an angle of about 25° with the reef (Friedman, 1968). Other typical species occurring in lower abundance include *Montipora granulata, M. lobulata* and *Echinopora gemmacea*. The soft coral *Sinularia leptocladus* covers large patches on the reef flat.

The upper fore-reef region is 50-70 m wide and 3-12 m deep. *E. gemmacea* is dominant, comprising 16% of the living surface and other typical species include *Acropora hemprichi, A. variabilis, Goniastrea pectinata* and *Stylophora prostrata*, as well a huge heads of *Goniopora savignyi* and *Lobophyllia hemprichi*; coral cover averages 81%.

The patch reef region, 30-40 m wide and 13-19 m deep, is poorest in coral abundance and cover, and has a predominantly sand bottom. The most abundant corals are *A. hemprichi* and *A. variabilis*, comprising 26% of living corals. *S. pistillata* and *P. lamellina* are occasionally found. The lower fore-reef region (40-60 m wide and 20-50 m deep) consists of a slope densely populated with corals, particularly *Porites lutea, A. hemprichi* and *M. lobulata*, which show a strong trend of increasing abundance with depth. Species exclusively limited to this zone are *Leptoseris tubulifera* and *L. fragilis*. Other species found here include *Mycedium tubifex, Echinophyllia aspera* and *Antipathes isidia*. Live coral coverage is 30-40% in the north and 80% in the south of the Reserve. Scattered coral colonies may occasionally be found in deeper water (Loya and Slobodkin, 1971).

Mergner (1971) developed a mapping approach with his extensive semi-schematic description of a transect through the northern fringing reef of Eilat which included data on the abiotic conditions in each of the bio-physiographic zones, including light intensity, water movements, and substrate. The distribution of the ten most important coral species, the names of the indicator species, and the width and depth range of the different zones were described. Of the 129 hermatypic coral species known from the Gulf of Eilat, 101 are found in the Reserve (Scheer and Pillai, 1983).

**Noteworthy Fauna and Flora** The Reserve has a rich coral reef fauna representing 90% of all species known from the Gulf of Eilat. It includes fish and invertebrates endemic to the gulf and rare species such as *Chaetodon semilarvatus, Antennarius* sp., *Platax orbicularius, Torpedo sinusperici* and *Monocanthus* sp. The molluscs *Charonia tritonis* and *Argonauta* have been recorded occasionally. Tridacnids are abundant; there is a high density of echinoderms *Diadema setosum* in the lagoon and a variety of sea urchins are common on the reef flat. Large crustaceans such as *Panulirus* are rare, but the Red Sea scyllarid *Scyllarides tridacnopagus* is sometimes found.

The Green Turtle *Chelonia mydas* and Hawksbill Turtle *Eretmochelys imbricata* are occasionally seen; Leatherbacks *Dermochelys coriacea* and Dugongs *Dugong dugon* have been recorded in the south but not in the north. Dolphins (Delphinidae) and sharks (Selachimorpha) are infrequent visitors. The dominant alga throughout the year is *Turbinaria elatensis*. Several species appear only in winter (*Hydroclathrus clatherutus, Padina sp., Cladophora sp., Jania* sp. and *Colpomenia* sp.), in blooms lasting 3-4 months. Some sandy bottom patches are covered with the seaweed *Halophila stipulacea* accompanied by garden eels.

**Scientific Importance and Research** The reef is easily accessible and the dry climate and calm water provide ideal conditions for research. A monitoring programme is under way, in collaboration with Israeli Universities dealing with marine ecology. Several studies on the effect of oil pollution on coral reefs have been carried out in the area (Fishelson, 1973a; Loya, 1972 and 1975; Rinkevich and Loya, 1977). Studies have also been carried out on soft corals (Benayahu, 1982), stony corals (Benayahu and Loya, 1977 and 1981; Fishelson, 1973b; Rinkevich and Loya, 1979; Schumacher, 1974; Shlesinger, 1984) and fish (Fishelson, 1970; Fishelson *et al.*, 1985). Work on the behaviour of reef fish and invertebrates is summarised in Fricke (1976). In 1978, an underwater habitat "Neritica" was established for research purposes on a reef at 10 m depth (Fricke, 1978 and 1979) and subsequently a submersible was used for more detailed research (Fricke, 1982; Fricke and Schumacher, 1983). Other studies have been carried out by Schmid *et al.* (1983).

**Economic Value and Social Benefits** An important area for tourism, encompassing the southern tourism development of hotels and diving centers. Diving and snorkelling are encouraged within the Reserve and educational trips and research are welcome. The Underwater Observatory co-operates with the Reserve to minimize damage by visitors. Another company operates glass-bottomed boats to view the fore-reef, from a base outside the Reserve.

**Disturbance or Deficiencies** The Eilat reef flats were exposed at midday during an unexpected and extremely low tide in September 1970, the low water level being 40 cm lower than predicted. Approximately 80-90% of the hermatypic corals on the flats were killed (Loya, 1976a). The Reserve is in the immediate vicinity of two major oil terminals and the general port. Oil pollution has been increasing rapidly over the past decade (Rinkevich and Loya, 1977). During 1972-73, approximately three big oil spills per month occurred at the Reserve, as well as many other minor spills (Loya, 1975) which were not officially recorded. Phosphate eutrophication coupled with chronic oil pollution may have been responsible for the expansion of the algal community at the cost of corals (Fishelson, 1973a). By 1973, a marked decrease in living coral cover was noticeable (Fishelson, 1973a) and in 1975 the Reserve was considered to be chronically polluted by oil and minerals (Loya, 1975; Rinkevich and Loya, 1977). The northerly wind and north-south shore current move any spills into the Reserve. A phosphate monitoring programme was carried out from 1979 to 1980 as a result of preliminary work by Shlesinger and Loya (1977). A gradient of dissolved phosphate concentration was found from the loading terminal north of the reserve, towards the southern beach (Schlesinger, 1980). Improvements were therefore made at the phosphate terminal to prevent effluent discharge and phosphate pollution is now a less serious problem although extraordinarily high levels do temporarily occur.

Long term publicity has virtually eliminated collection of corals and shells and fishing within the area.

**Legal Protection** The Reserve was established November 1964. The International Convention for the Prevention of Marine Pollution has been enforced (Anon., 1981). Fishing and collection of corals and shells and all other organisms (dead or alive) is forbidden. Scientific sampling requires special permits and is restricted.

**Management** Administered by Nature Reserves Authority (P.O. Box 667, Eilat 88105), which maintains a staff of five, including two wardens. A small entrance fee is collected at the main centre, which provides a variety of facilities for tourists, including rental of diving equipment. The Nature Reserve is open only during the day. Brochures, posters and fish identification guides are available. The visitors centre has a lecture room, an audio-visual slide programme and other educational services; other facilities are under construction. On the beach, shaded areas are provided. To prevent visitors walking on the reef, footpaths are marked by a series of floats and visitors are asked to keep to these. In deeper water, visitors may go where they wish, but three guide-posted underwater trails are provided to facilitate identification of marine organisms.

**Recommendations** Sand is added to some of the tourist beaches and consideration must be given to ensuring that this does not spread to the reserve via currents and wind.

# JORDAN

## INTRODUCTION

### General Description

The coastline of Jordan extends for 27 km along the north-east section of the Gulf of Aqaba, with the town of Aqaba in the north-east corner. Rainfall is very low, averaging only 22 mm per year, and evaporation is intense, exceeding 2000 mm per year. This results in an elevated salinity of about 42 ppt. Winds blow predominantly from the north-north-west to the south and seem to cause a general counter-clockwise current in surface waters of the Gulf of Aqaba (Hulings, 1979a; Leger *et al.*, 1986). There is a small tidal range but occasional unpredictable low tides expose the reef flat.

A general description of the coastline and sublittoral habitat is given in Mahasneh and Meinesz (1984). The coast has a discontinuous series of fringing reefs over a length of 13 km. These are found mainly around the headlands and are separated by bays (usually with seagrass beds) which correspond to the mouths of dry stream beds (wadis). The largest seagrass bed occurs in Al-Mamiah Bay (Mamlah Bay, Big Bay). Fringing reefs are better developed on the more exposed lengths of shore and are reduced to scattered coral patches in sheltered areas (Courboules *et al.*, 1986; Manière *et al.*, 1986; Manière and Jaubert, 1984 and 1985).

The reefs consist of a reef flat, never more than 150 m wide, often with a restricted and very shallow lagoon and corresponding back-reef. The seaward or fore-reef forms a small vertical cliff face (2-5 m), indented with numerous cavities and crevices, which then slopes to 20-40 m with numerous sandy troughs, before dropping vertically for 50 m. A depth of several hundred metres is reached very rapidly. To the north, the mountains on the shore come to the water's edge and slope steeply beneath the water surface. Here, the reef flat is narrow and the reef face small. In the south there are two well developed fringing reefs, 10 and 12 km south of Aqaba City (Bouchon *et al.*, 1981; Ormond 1978a). Although the Jordanian reefs are northerly and temperatures may drop to 20°C, they have a relatively high diversity of corals, 98 species having been recorded (Mergner and Schuhmacher, 1985).

The most diverse areas are the reef slopes of the fringing reefs. The dominant invertebrate species of different zones are listed by Mergner and Schumacher (1974) as follows: back-reef: *Favia speciosa, Platygyra lamellina*, the soft coral *Litophyton arboreum*, and the urchin *Diadema setosum*; reef flat: *Fungia fungites, F. speciosa, Stylophora pistillata*; reef crest: *Millepora dichotoma, Acropora variabilis, Montipora spp., Goniastrea pectinata, Porites spp., P. lamellina* and *L. arboreum*; fore-reef: *P. lutea, Acropora spp., Favia spp., Lobophyllia corymbosa, Echinopora gemmacea, G. pectinata*, and the soft coral *Xenia macrospiculata*. Three sites are particularly attractive for SCUBA divers: an underwater cliff by the power station at El Bordj and two sites within the proposed management zone (*see separate account*).

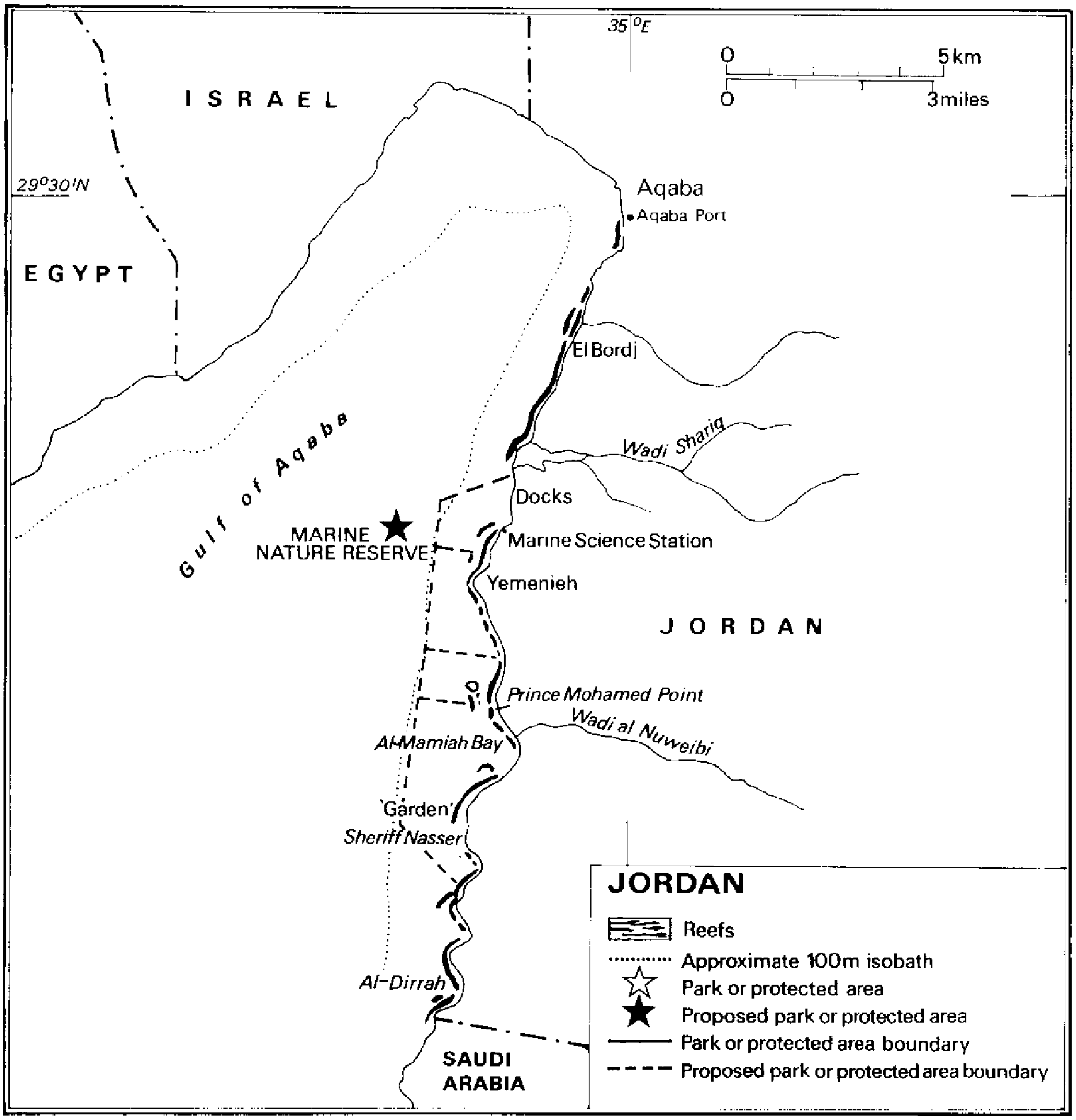
Research has been extensive since 1972 when a small marine station was opened by the University of Jordan. The new Marine Science Station, opened in 1982, is co-managed by the University of Jordan and the University of Yarmouk. There is a project to build a model aquaculture station (Clark and Vanderbilt, 1982). A programme "Ecology of the coral reefs and the surrounding waters of the Jordanian coast of the Gulf of Aqaba" was set up in 1978 as a co-operative effort between the University of Nice and the University of Jordan (Harmelin-Vivien and Bouchon-Navaro, 1981) and was extended to the University of Yarmouk in 1981. Of the 120 or so scientific publications, dissertations and abstracts published since 1972, about 48 were produced under the framework of the Franco-Jordanian agreement, through the scientific and technical activities of the French Oceanographic Mission in the Middle East (MOFMO).

Mergner and Schuhmacher (1974 and 1981) studied reefs 7 km south of Aqaba, and Mergner and Mastaller (1980) studied an area 1 km south of the Marine Science Station. Bouchon (1980) and Bouchon *et al.* (1981) described the scleractinian communities and the morphology and evolution of the Aqaba reefs. Other general descriptions include Manière and Jaubert (1985), Mergner (1979 and 1980), Mergner and Svoboda (1977), Ormond (1978a) and de Vaugelas (1984a). Recent studies include those of Gattuso and Jaubert (1984) and Gattuso (1985) on *Stylophora pistillata*.

Sediment communities are described by Grelet (1984 and 1985), Grelet *et al.* (1983 and in press), Hulings (1975a and b), Ismail (1984 and 1986), Ismail and Awad (1984), Mahasneh *et al.* (1985) and Wahbeh (1976). The callianassid crustaceans responsible for intense reworking of most of the soft-bottom habitats, including seagrass beds, have been studied by de Vaugelas and Saint Laurent (1984), and de Vaugelas (1983, 1984a and c, 1985a and b). Sediment distribution and properties are described in Freemantle *et al.* (1978), Gabrié and Montaggioni (1982), Hulings (1982), Hulings and Ismail (1978), de Vaugelas *et al.* (1983) and de Vaugelas and Naim (1982).

Seagrass beds have been the subject of extensive surveys including Doddema (1981), Doddema and Howari (1983), Hulings (1979b), Hulings and Ismail (1978), Hulings and Kirkman (1982), Jones *et al.* (in press), Wahbeh (1980, 1981, 1983, 1984, and in press), Wahbeh and Al-Eisawi (1985), Wahbeh and Mahasneh (1984 and 1985) and Wahbeh and Ormond (1980). Algae are described by Meinesz (1981), Mergner and Svoboda (1977), Natour *et al.* (1979) and Walker (1980). Metabolic studies were carried out by Bay (1982), Gattuso (1985), Gattuso and Jaubert (1984), Mergner and Svoboda (1977), Pascal (1981), Pascal and Vacelet (1982), Svoboda (1978) and Wahbeh (1983). Currents, nutrients and plankton are described by Hulings (1979a), Hulings and Abu Hilal (1983), Leger and Artiges (1978), Leger *et al.* (1986), Natour and Nienhuis (1980), Seguin (1982), Seridji (1984), Vaissière and Seguin (1982 and 1983) and Seguin and Vaissière (1982). Molluscs from the intertidal zone are described by Hulings (1985a and b).

Fish life is moderately diverse (Abdul-Nabi, 1977 and 1980; Bouchon-Navaro, 1980; Bouchon-Navaro and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Prince Mohamed Point
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Al-Mamiah Bay
'Garden'
Sheriff Nasser
Al-Dirrah
SAUDI ARABIA
JORDAN
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Proposed park or protected area
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Proposed park or protected area boundary

Harmelin-Vivien, 1981; Harmelin-Vivien and Bouchon-Navaro, 1981; Ormond, 1978a and 1980a; Post and Svoboda, 1980; Wahbeh and Ajiad, 1985a and 1985b). Comparative surveys of coral reef fish in the Red Sea and Gulf of Aqaba have shown that some species are common at Aqaba but rare or absent elsewhere. The Red Sea endemic *Paracheilinus octotaenia* occurs on Aqaba's deep water reefs (Ormond, 1980a).

**Reef Resources**

There is considerable conflict between the different uses to which the small coastline is put (Ormond, 1980b). The north coast is occupied by the royal palace and hotels and is fronted by a sandy beach. Port facilities cover much of the area from El Bordj to just north of the Marine Science Station. The area to the south is proposed as a tourist area and industrial and military developments are planned for the area beyond this. As much land as possible is needed for port expansion and industrial development but the coast is of significant recreational and scientific value (Ormond, 1978a). After industrial and port development, tourism is the second most important activity, with five well established hotels. The Marine Science Station Aquarium is a major attraction for tourists and plays an important educational role as it is visited by numerous parties of school children. Diving was a major attraction until 1980 when the number of foreign visitors declined. Considerable efforts are now being made by the Aqaba Region Authority to attract European and American tourists and the dive sites which were once popular may become so again and therefore need some protection (Ormond, 1978a; de Vaugelas *in litt.*, 3.3.85). An international diving centre was opened in December 1986 by the Aqaba Regional Authority, with the technical assistance of MOFMO (de Vaugelas *in litt.*, Jan. 1987).

**Disturbances and Deficiencies**

The reefs suffer periodic emersion which results in dead eroded summits of the massive poritid and faviid corals. Low tides in 1983 and early 1985 caused exceptional emersions and corals underwent heavy mortality. The dead colonies were colonized by *Ulva* within a few days. In 1985, the effects of the 1983 emersion were still visible as a straight horizontal line on the massive heads (de Vaugelas *in litt.*, 3.3.85). Although the stable climax communities of the reef system seem to have adapted to these conditions, additional manmade perturbations could disrupt this fine balance causing far reaching disturbances. Periodic population explosions of the sea urchins *Diadema setosum*, *Echinothrix diadema* and *Tripneustes gratilla* in the 1970s may have been due to such temporary localized damage (Benayahu and Loya, 1977; Mastaller, 1979; Mergner, 1981; Mergner and Mastaller, 1980; de Vaugelas *in litt.*, 3.3.85).

A detailed description of damage to coral reefs and benthic communities is given in Mahasneh and Meinitz (1984). The reefs are vulnerable to pollution from a variety of sources including chemical and thermal effluents, sewage (Ismail and Awad, 1984; Wahbeh, 1985; Walker and Ormond, 1982) and oil. There was a large oil spill in 1975 and 1976 in the University area but the reef recovered within four months (Mergner, 1981). There is localized damage from phosphate pollution and a dust cloud may be seen above Aqaba harbour (Abu-Hilal, 1985; Freemantle *et al.*, 1978; Hashwa, 1980; Hulings, 1982; Ismail and Awad, 1984; Jaubert *et al.*, 1982; Madi, 1982; Mulqi, 1978; Vacelet, 1986; Walker and Ormond, 1982). Phosphate induces algal growth, as seen on the reef flats near the harbour, which kills the corals *Acropora, Seriatopora* and *Stylophora* (Mergner, 1981), probably as a result of increased sedimentation caused by the alga. The rate of death of *S. pistillata* is four times as great in areas polluted by sewage and phosphate dust (Walker and Ormond, 1982), although living colonies are still found attached to the metal piles supporting the loading berth; the reason for this anomaly is not known (de Vaugelas *in litt.*, 3.3.85).

Direct destruction of the reefs has been caused by infilling during the expansion of port facilities and has occurred through dynamiting by fishermen, especially in Al-Mamiah Bay and Al-Dirrah (Al-Durah, Last Bay, Wadi 1) (Mahasneh and Meinesz, 1984; Ormond, 198Ob). The direct destruction of corals by anchors and chains may be a major cause of reef destruction and is being studied (de Vaugelas *in litt.*, 3.3.85).

**Legislation and Management**

Fishing is controlled under the Ministry of Agriculture Law No. 20/1973 (items 180 to 186) (4th Section Fish resources). Under the same law coral collecting and spearfishing are forbidden and subject to fines. Dynamiting by fishermen has been forbidden since 1967 and legislated under the 1973 law. The 1975 Ship Act No. 25 (Item No. 6 of the 1959 Aqaba Port regulation No. 18) prohibits the disposal of chemicals and toxic products, including oil, into the sea and fines range from 1000 to 10 000 JD. Jordan has ratified the Regional Convention for the Conservation of the Red Sea and Gulf of Aden Environment. The Aqaba Regional Authority has a blue-print for a five-year plan starting in 1989 which will include improvements in tourist facilities, cleaning of beaches, completion of a sewage system (probably in 1987) and revitalisation of the fishing industry. There is now effective control of commercial ships by the Port Authority and RSCN patrol boat and coastguards. In 1983, 47 boats were charged with water pollution resulting in 87 500 JD (ca US $250 000) of fines (Mahasneh pers. comm. to de Vaugelas, 1985).

The National Park system was established in the early 1970s under the Ministry of Agriculture and is administered by the Royal Society for the Conservation of Nature (RSCN). The RSCN is part of the Protection of the Environment Office in the Aqaba Region Authority. A Marine Nature Reserve was declared to the south of the Marine Science Station but legislation has not been approved yet (*see separate account*).

**Recommendations**

Ormond (1978a) proposed a system of Reserves (*see separate account*). In addition to the existing Marine Nature Reserve it is recommended that a few particular sites, e.g. in front of some of the major hotels and at the power station at El Bordj, should be established as "sites of recreational and scientific value". New laws concerning the protection of the marine environment are to be discussed soon. The installation of permanent moorings along the coast should be considered a high priority. Wahbeh and Mahasneh (1982) give a general description of coastal management requirements and further information is given in UNEP (1980). Further recommendations for improved coastal management are given in Ormond (1978a and b), including pollution monitoring, provision of park staff, educational and interpretive facilities and a marine aquarium. These recommendations are being used in the current development of a Marine Park (*see separate account*).

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## AQABA MARINE NATURE RESERVE AND PROPOSED MARINE PARK AND ENVIRONMENTAL MANAGEMENT ZONE

**Geographical Location** Central third of the Jordanian coast, from the Marine Science station south to the headland north of Al-Dirrah (Last Bay, Wadi 1).

**Area, Depth, Altitude** Ormond (1978a) recommended that the proposed Marine Park and Environment Management Zone should extend 0.5-1 km out to sea.

**Physical Features** The coast consists of a series of essentially similar embayments in each of which a comparatively similar and fairly wide range of communities is present, including rocky shore, reef flat, reef face, fore-reef, sandy shore, sandy bottom and seagrass ecosystems (Ormond, 1978a)

**Reef Structure and Corals** A number of sites in this area are described in Ormond (1978a). There are two particularly interesting ones: (i) in the bay south of Yemenieh a mound on the south side rises from deep water and has the highest coral cover and large shoals of planktivorous fish, and (ii) the "garden" at the northern boundary of Sheriff Nasser's establishment where there are scattered mounds and clusters of coral on a sandy sloping bed interspersed with seagrass.

Mergner and Mastaller (1980) describe an area in the southern part of the reef lagoon, 1 km south of the Marine Science Station. Mergner (1980) describes an area beside University Bay, close to the Marine Science Station.

**Noteworthy Fauna and Flora** *Gorgasia sillneri* the garden eel was found at the "garden" (Ormond, 1978a). A new species of callianassid shrimp *Callichirus laurae* was discovered in 1982 (de Vaugelas and Saint Laurent, 1984).

**Scientific Importance and Research** The area was surveyed by Ormond (1978a) and considerable work is carried out at the Marine Science Station (*see* "Introduction"). A monitoring programme on water quality was initiated in January 1985 in the zone in front of the Marine Science Station. A study on metal pollution in sediment is also under way (Abu-Hilal and de Vaugelas, in prep.).

**Economic Value and Social Benefits** Several sites are used by SCUBA divers (Ormond, 1978a). A new diving centre and proposed marina will provide a focus for recreational activities (de Vaugelas *in litt.*, Jan. 1987).

**Disturbance or Deficiencies** The reefs in this area are under threat from industrial development; anchor damage; localized phosphate pollution; chemical pollution from the industrial complex to the south, a fertilizer plant, a potash plant, and a plywood factory; hot water effluent from the Aqaba Power Plant and other industrial activities; sewage pollution and oil spills. Some damage may have been done by explosives used in the course of a geophysical research study (Mahasneh and Meinesz, 1984; Ormond, 1978a).

**Legal Protection** In January 1985 a Marine Nature Reserve was declared to protect the 2 km length of reef south of the Marine Science Station (de Vaugelas *in litt.*, 3.3.85) but legislation has not yet been approved (Mahasneh *in litt.*, 4.3.87).

**Management** The Marine Nature Reserve is to be managed by the Aqaba Region Authority.

**Recommendations** A detailed proposal for the establishment of a Marine Park was prepared by Ormond (1978a). This was to cover the central third of the Jordanian coast with two smaller, more fully protected reserve areas within it. One of these, the area around the University Marine Station, has now been protected. A Central Reserve area was proposed for the section stretching 1.4 km north of Prince Mohamed Point. A Marine Environmental Management zone surrounding the whole Park was also recommended (Ormond, 1978a and 1980b), within which partial protection would be given to marine life. Detailed recommendations for the implementation and management of these schemes is given in Ormond (1978a). This proposal is being used as one basis for a recent overall socio-economic planning study of the Aqaba region, and the planning of an essentially similar Marine Park area to be established on the central part of the coast (Ormond *in litt.*, Feb. 1987).

# KENYA

## INTRODUCTION

### General Description

The coastline of Kenya extends a little over 450 km along the East African coastline, from about 1°30'S at the Somali border to nearly 5°S at the border with Tanzania. In common with most of this region, the continental shelf is narrow, and supports fringing reefs and patch reefs which lie mostly 0.5-2 km off shore (UNEP, 1984). The shoreline has an extensive fossil reef which is raised a few metres above present sea-level. Planation of this has resulted in areas along the shore with reef flat, although these are probably not actively accreting. Live fringing reef is found a little to seaward in several areas, notably at Malindi and Watamu. Off shore, along most of the coast, patch reefs rise from water a few metres or a few tens of metres in depth. Gaps in the reefs occur near the mouths of rivers, notably the Tana and Sabaki. There are an estimated 530 sq. km of mangroves (Brakel, 1981), and extensive sandy beaches.

The coastal climate, currents and winds are dominated by the seasonal monsoon winds. From April to October, winds are from the south-east while for the rest of the year they blow from the north-east. Currents are derived from the South Equatorial Current, which divides on reaching the African coast. The northerly flow, the East African Coastal Current, flows along the Kenya coast causing a northward water movement for most of the year. Current velocity is high, averaging between two and four knots. Under the influence of the north-east monsoon, in the northern part of the country in particular, the current reverses and flows southwards. Further information is given in Hove (1981) and Newell (1957).

Tides are of the mixed, semi-diurnal type, with spring amplitudes exceeding three metres. These cause strong, localized currents in breaks around the reefs which are superimposed onto the overall longshore current. Annual rainfall exceeds 800 mm, and there are freshwater inputs from rivers, the main drainage lines being the Tana, Sabaki and Ramisi, and a few seasonal rivers. Since reefs are limited to the narrow continental shelf, these inputs have an important controlling effect, through both freshwater and sediments (Couper, 1983, Hamilton and Brakel, 1984). Brakel (1984) has analysed the seasonal dynamics of sediment plumes from the Tana and Sabaki Rivers using Landsat images. The long rains of April-May cause large pulses in river derived sediments, which are transported north with the East African Coastal Current. The shorter rains in November cause a second peak of discharged sediments which may be transported south along the shore.

There have been very few biological and ecological studies of the reefs, apart from the work of Hamilton (1975) and Hamilton and Brakel (1984) but research is now under way at the Kenya Marine and Fisheries Research Institute in Mombasa (Muthiga *in litt.*, 20.1.87). The best known reefs are in the Malindi-Watamu area (*see separate account*). Jones (1969) briefly describes the reefs at Shimoni, Kilifi, Horns Bay (10 mi. (16 km) north of Kilifi) and Ras Ngomeni (north of Malindi). Brakel (1979) mentions the reefs at Ngomeni and Kipini as being of note. McClanahan and Muthiga (in press) studied reefs at Diani, Malindi and Kanamai in relation to sea urchin density. Separate accounts are given for the reefs at Kiunga, Ras Tenewi, Kisite and Diani.

About 140 species of coral have been recorded (Hamilton, 1975). *Goniastrea* is particularly important (for example at North Reef, Malindi (Keech *et al.*, 1979)) and contributes heavily to the growing edge of the mainland fringing reef (Hamilton and Brakel, 1984). It tends to become less common towards the south, where *Platygyra* increases in importance. Species of *Acropora* and pocilloporids are common, with the former being the most important genus on the reefs generally, as is the case in most parts of the Indian Ocean. *Porites* is also important, and both branching and massive species are found. On some submerged reefs, for example in the Malindi area, *Galaxea clavus* is unusually the dominant and indeed almost the only coral (Ray, 1969). The octocoral *Heliopora* is not common, while *Millepora* is common but never dominant (Hamilton and Brakel, 1984).

Bock (1975) provides a checklist of fish at Kilifi Creek. Cowries (Cypraeidae) are described by Stevenson (1971). Frazier (1975) and Groombridge (1982) report provisional estimates of about 50 female Hawksbill Turtles *Eretmochelys imbricata* nesting annually, mainly on islands in the north, and fewer than 200 Green Turtles *Chelonia mydas* nesting. Loggerheads *Caretta caretta*, Olive Ridley *Lepidochelys olivacea* and Leatherbacks *Dermochelys coriacea* are recorded occasionally at sea.

### Reef Resources

The relationship of the Kenyan fisheries to coral reefs is discussed by Brakel (1981). The most important fishery areas are in the north in Ungwana Bay, off shore near Lamu and in areas 20 and 80 km north of Lamu. Malindi and Lamu are important fishing ports (Dubois *et al.*, 1985; Muslim, 1983). In the 1970s, the catch from these northern reefs was about 4.9 ton/sq. km, and maximum sustainable yields along this part of the coast have been estimated at 5 tons/sq. km (Gulland, 1979).

Reefs in easily accessible areas, such as Mombasa, Malindi and Watamu, are an important source of revenue for the tourist industry (Achieng, 1981; Muslim, 1983). The importance of reef-related recreational activities on the Kenyan coast is described in Brakel (1979); net foreign exchange earnings for the marine recreation sector in the late 1970s was K£420 000. Of the 500 000 visitors to Kenya annually, at least 10% visit Malindi or other coastal resorts (Pertet, 1984b). General information on the socio-economic importance of the coast is given in UNEP (1984).


KENYA
Reefs
Approximate 100m isobath
Park or protected area
Proposed park or protected area
Park or protected area boundary
Proposed park or protected area boundary
0 100 200 km
0 100 miles
40°E
0°
5°S
SOMALIA
K E N Y A
TANZANIA
Indian Ocean
Nairobi
R. Tana
R. Athi
R. Galana
Witu
Kipini
Lamu I.
Pate I.
KIUNGA MARINE NATIONAL RESERVE
RAS TENEWI
Ras Shaka
Ras Ngomeni
Malindi
Watamu
Kilifi
MALINDI-WATAMU MARINE NATIONAL PARKS
Mombasa
Diani Beach
DIANI
Kaya Kinondo
Gazi Bay
Chale I.
Shimoni
KISITE-MPUNGUTI MARINE NATIONAL PARK AND RESERVE

**Disturbances and Deficiencies**

The agricultural methods used inland are leading to severe erosion with subsequent flushing of sediments through the river systems, particularly the Tana and Athi (Sabaki). This is appearing to have a marked deleterious effect on some inshore environments, and its effects are increasingly felt in some coral reef areas, particularly Malindi and areas further south (Brakel, 1984; Dubois *et al.*, 1985; Muslim, 1983; Pertet, 1984b; UNEP, 1984). Pollution is potentially a problem, particularly from the cement industry, chemical and textile plants near Mombasa, domestic effluent, mining and oil from tanker traffic and exploratory activities.

Tourism had caused considerable reef destruction in several areas by the 1960s (Ray, 1969). Overcollection of shells and coral, which were collected by the boat load, has been a serious problem (Anon, 1982a; Brown, 1977; Evans *et al.*, 1977; Kendall, 1984; Samoilys, 1981). Large quantities are collected in the Shimoni, Lamu and Kiunga areas and even within the marine parks. Many species are probably being overexploited and careless collecting methods have led to habitat damage. The large profits to be made from selling shells and corals to tourists ensure that the trade continues. Despite controls, nearly 144 tonnes of corals and shells were exported in 1982, mainly to the U.S.A., Italy and India (Foreign Trade Statistics).

It has been suggested that disturbance of the reefs through overfishing and overcollection of shells may cause increases in population numbers of the sea urchin *Echinometra mathaei* (McClanahan, in press; McClanahan and Muthiga, in press; Muthiga and McClanahan, 1986). Reef lagoons with hard substrate (i.e. dead or living coral) in protected or remote areas generally have a high density of finfish, high coral cover and low density of urchins, as at Malindi Marine National Park. The reverse is true in heavily exploited areas such as Diani, and an intermediate situation is found in medium-populated areas such as Kanamai.

Inadvertent trampling of reefs is cited as one important cause of shallow reef destruction in the Malindi area, coupled with damage from boats (Keech *et al.*, 1979), although within the Park this is now largely controlled. There has been little dynamite fishing in Kenya, compared with neighbouring countries but several methods used on or near reefs are destructive and certainly sub-optimal, involving incidental capture of dugong *Dugong dugon*, turtles and small reef fish. Populations of dugong and turtles are clearly much lower than in the recent past. Modern fishing methods are much more destructive than traditional methods (Ray, 1969). Brakel (1981) discusses the potential impact of deteriorating reefs on the coastal fisheries.

**Legislation and Management**

Muslim (1983) describes legislation relating to coastal issues, including the role of the Department of Fisheries. Shell collecting was banned in the 1970s, but after only a few months it was substituted by a quota systems as a result of pressure from politicians representing the fishermen and collectors. This is considered ineffective although it has been suggested that some reef recovery will probably occur given suitable management of Marine Parks and Reserves (Anon., 1982a; Brown, 1977; Keech *et al.*, 1979; UNEP, 1984). The East African Wildlife Society has tried to increase public awareness of the problem through the production of a poster to persuade tourists not to buy corals and shells (Anon, 1981).

Damming is reported to have noticeably reduced siltation at the mouth of the Tana river and marine fisheries seem to be improving (UN/Unesco/UNEP, 1982) (*see account for* Malindi/Watamu).

National Parks and Reserves come under the Wildlife (Conservation and Management) Act of 1976, Legal Notice 219, and are administered by the Wildlife Conservation and Management Department of the Ministry of Tourism and Wildlife. The general rules and regulations of the terrestrial Parks and Reserves are therefore enforced in the marine protected areas where applicable. In Marine National Parks, the flora and fauna are fully protected, any disturbance or collection of organisms is prohibited, and the introduction of animals or plants is prohibited. In Marine National Reserves, specified traditional methods of fishing are allowed, but collection of shells and corals is prohibited, as is fishing by the use of poisons, spearguns and dynamite. Both Parks and Reserves are patrolled by the Wardens and Rangers, and the National Reserves are administered by the District Councils (Brakel, 1979). Observation of marine life from glass-bottomed boats or with the use of snorkelling or diving equipment requires the payment of standard park admission fees but many activities, such as passage or anchorage of boats and swimming off the beach, are free of charge.

A large proportion of the reefs fall within the following protected areas which are described in separate accounts:

- Malindi and Watamu Marine Complex (National Reserves, National Parks and Biosphere Reserve)
- Mpunguti Marine National Reserve
- Kisite Marine National Park
- Kiunga Marine National Reserve and Biosphere Reserve

**Recommendations**

Pertet (1984a and b) and Kinyanjui (1983) discuss management of, and problems within, Kenya's marine protected areas and recommend improvements. There is still a need for more detailed information on reef distribution and ecology, but there is also an urgent need to improve management of the existing protected reef areas, establish coastal zone management programmes and develop strategies to deal with the potential impact of siltation. As a result of studies on sea urchin populations, it has been recommended to IUCN/WWF that there should be a ban on the collection and sale of the Bullmouth Helmet Shell *Cypraecassis rufa* which is heavily collected and is an urchin predator and that further work should be carried out on the impact of shelling and potential uses for sea urchins (McClanahan and Muthiga *in litt.*, 20.1.87). A Wildlife and Fisheries Training Institute has been established in Naivasha with the assistance of the World Bank, to train wardens for both terrestrial and marine protected areas.

Additional marine protected areas including reefs have been proposed as follows (*see separate accounts*):

- Diani Marine National Park Complex
- Ras Tenewi Coastal Zone National Park

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## DIANI PROPOSED MARINE NATIONAL PARK COMPLEX

**Geographical Location** South of Mombasa from Kaya Kinondo in the north to Chale Island in the south; 4°15'S, 39°37'E;

**Area, Depth, Altitude** Approx. 250 ha.

**Land Tenure** Trust land under the jurisdiction of Kwale County Council.

**Physical Features** The area includes Similani, Kaya Kinondo and Chale Island. Wave action is very strong.

**Reef Structure and Corals** Hamilton (1975) describes the fringing reef at Diani. A reef crest 200 m wide is separated from the coral sand beach by a distance of up to 1 km and by water 4-5 m deep. In the channel or lagoon there are mixed corals, especially *Acropora* species, while in the surge channels pocilloporid corals, *Acropora, Goniastrea retiformis* and other species grow, especially on the outer edges. On the reef slope at 7-16 m soft corals dominate, though *Porites* and *Echinopora lamellosa* are common.

**Noteworthy Fauna and Flora** The mangrove swamps in Gazi Bay to the south of the Park are described in Barnett and Briggs (1983). The timber tree *Calophyllum inophyllum* was used in the past for boat building. Similani has important bat roosting caves for a number of species including the large fruit bat *Rousettus aegyptiacus* and the insect eating bat *Hipposideros commersoni*. The islands are important nesting sites for several species of terrestrial bird. Further information on vegetation and fauna is given in IUCN (1987). Bock (1972) provides a preliminary checklist of lagoonal fish at Diani.

**Scientific Importance and Research** The reefs around Chale Island were briefly visited by the University of Bristol Kenya Expedition 1982 (Barnett and Briggs, 1983). The sea urchin *Echinometra mathaei* has been studied on the reefs off Diani by Khamala (1971) and Muthiga and McClanahan (1986).

**Economic Value and Social Benefits** Diani Beach is one of the most popular tourist beaches in East Africa. Beach houses have been built at Leisure Lodge outside the proposed Park.

**Disturbance or Deficiencies** Shell collecting and finfishing have been intensive on the reefs. It has been suggested that removal of predators in this way may have contributed to the observed population increase of the urchin *Echinometra mathaei* over the last 15 years, although naturally occurring fluctuations may also play a role (Muthiga and McClanahan, 1986). The bat population is threatened by loss of habitat, which is being destroyed for the construction of beach houses. Contamination from insecticide toxins is a potential threat and there are feral goats and cattle on the island. Other disturbances are hunting, burning, snaring of animals and cutting of timber on the mainland (IUCN, 1987).

**Legal Protection** According to Pertet (1984a), Chale Island is well protected although its legal status is not known.

**Management** None.

**Recommendations** The area has been proposed as a National Park and efforts should be made to implement some form of protection urgently on account of the importance of tourism and the impact that this may already be having on the reefs.

## KISITE MARINE NATIONAL PARK AND MPUNGUTI MARINE NATIONAL RESERVE

**Geographical Location** South coast off Shimoni, south of Wasini Island, 6 km from Tanzanian border; 4°0'-4°44'S, 39°21'-39°26'E.

**Area, Depth, Altitude** Total area is 3901 ha: Kisite Marine National Park covers 2800 ha, Mpunguti Marine National Reserve 1100 ha; the islands cover about 18 ha; max alt. about 5 m.

**Land Tenure** Government expropriated, under trusteeship.

**Physical Features** The complex covers a marine area with four small waterless coral islands: Kisite, Mpunguti ya juu, Mpunguti ya chini and Jiwe la Jahazi. These have considerable reefs surrounding them. Little information is available on this area but a brief description is given in Jones (1969).

**Reef Structure and Corals** The leeward reef is described by Hamilton (1975). There is a narrow sandy beach leading to an immersed reef flat supporting mixed corals. Coral cover and diversity of the reef edge and reef slope is very high. *Acropora formosa* thickets, *Galaxea clavus* and other *Acropora* species dominate and branching *Porites* species and fungiids are conspicuous. Soft corals are important on the reef flat and on the slope.

**Noteworthy Fauna and Flora** IUCN (1987) list marine algae found in the area, and some of the marine invertebrates and fish. Seagrasses *Cymodocea serrulata* and *Syringodium isoetifolium* cover large areas of the reefs around the islands. Checklists for fish at Kisite and corals at Shimoni are also available (Didham *in litt.*, 1.11.85). The offshore islands are important for a number of pelagic birds including breeding colonies of Roseate Terns *Sterna dougallii* and Sooty Terns *S. fuscata*.

**Scientific Importance and Research** No research has been conducted on the reefs of this area.

**Economic Value and Social Benefits** The local population is dependent on fishing but tourism is becoming increasingly important. There were 3899 visitors in 1980. Cottage hotels have been established and there are other facilities in the fishing village. Boats can be hired in Shimoni and there is a restaurant on Wasini Island (IUCN, 1987).

**Disturbance or Deficiencies** The Mwamba Kitugamue reef on the Tanzanian border was damaged by blasting sometime ago and has also suffered from infestation by *Acanthaster planci* (Didham *in litt.*, 1.11.85). Slow regeneration has been reported. The island bird colonies were frequently raided before the area was protected. Illegal fishing and extensive shell collecting have been widespread (Anon., 1974; IUCN, 1987; Jones, 1969; Pertet, 1984a).

**Legal Protection** Originally established as a single protected area. However, as a result of pressure from fishermen, Mpunguti Marine National Reserve, in which fishing is permitted, was separated from Kisite Marine National Park to the south, on 10.5.78 under Legal Notice 91 and Legal Notice 92 respectively; both were published in the Kenya Gazette 9.6.78.

**Management** Over thirty persons are employed as wardens, rangers and support staff, and the park headquarters are at Shimoni. Address of administration is: Kisite / Mpunguti Marine National Park, PO Box 55, Ukunda, Kenya. Although the Park cuts across traditional fishing grounds, local fishermen are allowed free passage through certain sections to the open sea (Anon., 1974).

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## KIUNGA MARINE NATIONAL RESERVE AND BIOSPHERE RESERVE

**Geographical Location** Northern part of the Kenya coast, in the Lamu District of the Coast Province, 10 mi. (16 km) south of the Somali border; includes water to approximately 8 km north-east of Pate Islands; 1°45'-2°00'S, 41°20'-41°25'E.

**Area, Depth, Altitude** The Biosphere Reserve covers about 600 sq. km and includes the marine area contiguous to Dodori National Reserve; the National Marine Reserve covers 25 sq. km; sea-level to 30 m.

**Land Tenure** Offshore islands and mangrove swamps are State owned and administered by Lamu County Council.

**Physical Features** Physical water conditions are probably similar to those of Malindi (*see separate account*) although little data is available. Sediments from the Tana River will seasonally reach the area (Brakel, 1984). On the coastal strip there are sandy beaches, with sand dunes and a dry coastal shrubby forest. The coast consists of parallel lines of old and living reefs, one line situated 1-10 mi. (1.6-16 km) off shore forming a chain of about 50 calcareous islands, composed of coral and organic debris. Intertidally there are areas of sand and mud, some of which have been stabilized by marine angiosperms. The water between the islands and coast is sheltered and calm.

**Reef Structure and Corals** No details are available on the structure or biological character of the coral reefs which parallel the coastline, adjoining the offshore islands, and are said to be in excellent condition.

**Noteworthy Fauna and Flora** One of the principal reasons for the establishment of this Marine Reserve was to protect the important large nesting colonies of migratory seabirds on the offshore islands (Pertet, 1984a) including Sooty Gull *Larus hemprichii*, Roseate Tern *Sterna dougallii*, White-cheeked Tern *S. repressa* and Bridled Tern *S. anaethetus*. Cooper *et al.* (1984) list breeding figures for seabirds on Kiunga-Tenewe Islands. The 8000 breeding pairs of Roseate Terns form the largest single population of this species in the world. Other breeding species include a large population (5000 pairs) of Sooty Tern *S. fuscata* and a few pairs of Brown Noddy *Anous stolidus*. Green Turtle *Chelonia mydas* are common. Dugong *Dugong dugon* frequent the few creeks in the Reserve. In the sheltered tidal waters between Mwanzi and Mkokoni stands of mangrove, dominated by *Rhizophora mucronata*, are present which also support a diverse avifauna. Marine flora and other aspects of the terrestrial biota are described in more detail in IUCN (1987).

**Scientific Importance and Research** A marine research station has recently been constructed, including laboratories and staff and visitor accomodation.

**Economic Value and Social Benefits** Economic benefits are expected to derive from the establishment of the Marine Reserve but at present, this is the least developed of Kenya's marine parks. Certain water sports are allowed, including water-skiing, and passage of boats is permitted. Kiunga is a fishing village.

**Disturbance or Deficiencies** There has been some damage of the reefs through the collection of corals and shells for sale and for burning for lime, but this has not been extensive. There has been poaching of the Green Turtle and of turtle eggs from the nesting beaches, but attempts are being made to bring these under control. Poaching of Dugong also occurs (IUCN, 1987).

**Legal Protection** Kiunga Marine National Reserve was gazetted in 1979, by Legal Notice No. 291. It was accepted as a Biosphere Reserve in 1980.

**Management** Coastal waters are under the supervision of the Fisheries Department and the Wildlife Conservation and Management Department of the Ministry of Environment and Natural Resources. A buffer zone is provided by Dodori National Reserve which lies between the Marine National Reserve and the rest of the mainland. A staff of about 45 wardens, rangers and support staff is required. The administration address at present is: PO Box 82, Lamu, Kenya.

**Recommendations** The Reserve is the least developed of Kenya's Marine Parks. Three stages of scientific work have been proposed to be carried out by the newly established marine research laboratory: a basic resources inventory for the area; a more detailed study of the fauna and flora, and research into the environmental problems, leading to a comprehensive management plan (IUCN, 1987). There is a need for training of local scientists, which will, in the initial phases, require cooperation and support from international institutions such as Unesco.

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## MALINDI MARINE NATIONAL PARK AND WATAMU MARINE NATIONAL PARK (MALINDI/WATAMU MARINE NATIONAL RESERVE, MALINDI/WATAMU BIOSPHERE RESERVE)

**Geographical Location** South of Malindi, Kilifi District; 88-120 km north of Mombasa; 3°14'-3°25'S, 39°57'-40°11'E.

**Area, Depth, Altitude** Marine National Parks total 1600 ha; Marine National Reserves total 21 309 ha. Malindi MNP covers 630 ha, with a land base of 5 ha at Casuarina Point; Watamu MNP covers 1000 ha with a 2 ha land base; Watamu Marine National Reserve covers 1000 ha and includes the whole of Mida Creek to high water mark; Malindi Marine National Reserve covers the whole area and extends 5 km to sea, 30 km along the coast and covers 21 300 ha. Biosphere Reserve also covers the entire area. The reef slopes drop to 20 m depth or more in some places but many reef areas are considerably shallower.

**Land Tenure** State ownership, but bordered for much of its length by private land.

**Physical Features** The south-èast monsoon from April and October, brings strong trade winds, cool temperatures and heavy rainfall and creates a northerly current of up to 4 knots. The north-east monsoon from November to March brings dry northerly winds and causes current reversals. These bring very turbid water from the Sabaki River (known as the Athi in its upper reaches), 10 km north of Malindi, into the northern end of the area, reducing water visibility to almost zero (Keech *et al.*, 1979). For the most part, water clarity is good, and temperatures are fairly constant at about 26°C. Monthly rainfall varies between 2 mm and 390 mm (IUCN, 1987). A summary of the hydrological and climatological characteristics of the area is given by DuBois *et al.* (1985).

In this area the continental shelf is extremely narrow, with a sharp drop in depth a short distance from shore. The Malindi/Watamu Marine National Reserve encompasses the two Parks. In the north, Malindi Marine National Park has a fringing reef, to seaward of which is Barracuda Channel, and then a collection of offshore reefs. Notable amongst these are Malindi Reef, Leopard Reef and North Reef. North Reef is the largest reef (2 x 1 km), with a sand cay on the west side. Beds of the seagrass *Thalassodendron ciliatum* and isolated coral heads dominate the northern part. The "Coral Gardens" lie in a sheltered lagoon on the south-east side of North Reef. Tewa Reef is a submerged structure south-east of North Reef and is notable because it is composed almost entirely of *Galaxea clavus* which forms banks 4-6 m high and tens of metres across. Where this collapses, *G. fasicularis* colonizes, together with *Acropora* species.

For much of the length between the Parks there is a fringing reef which is near shore in the north and south but swings out to over 1 km from shore in the central region. Sediments behind the reef support seagrasses of several genera, including *Thalassia, Cymodocea* and *Halodule*. In some parts, these grade into mangrove stands, while other areas have sandy beaches. Small cliffs border parts of the coastline; these are mostly formed from raised fossil reef.

Watamu Marine National Park has been described by Jones (1969), although coral reefs received less attention than soft substrates. Turtle Bay marks the northern end and is bordered by raised limestone cliffs which drop to a rock platform at about 1 m above datum. This platform is a common feature of this part of the coast, and a part of it forms the roof of the Big Three Caves in the Mida Channel. Whale Island is situated at the mouth of the creek. The most abundant marine community of this area is the seagrass *Cymodocea ciliata*, which extends from the littoral zone to 5 m below sea-level. Corals exist on the reef platform between the seagrass areas and the outer edge.

**Reef Structure and Corals** Reefs in this region have been described by Anon. (1972), Brander *et al.* (1971), Jachowsky (1975), Jones (1969) and Keech *et al.* (1979). Hamilton (1975) describes North Reef in Malindi Marine National Park. On the eastern side is a channel 25 m deep, and a moat. Most of the reef flat dries at low tide and is dominated by *Goniastrea retiformis* in microatoll form, interspersed with *Acropora* colonies, especially towards the south. *G. retiformis* is also the dominant species on adjacent reef slopes, although the back reef slopes are dominated by *Galaxea*. On the landward side coral cover is less than 50%, with much of the substrate being occupied by *Halimeda* and rubble (Hamilton, 1975).

Malindi Marine National Reserve includes a 200 m wide portion of the fringing reef at Silversands with a shallow moat supporting seagrass beds. This is in a very sheltered position due to the protection by several offshore reefs. A wide range of corals was found by Hamilton (1975), of which *Goniastrea retiformis* was particularly important.

In the area between the two Marine National Parks there appear to be few patch reefs seaward of the fringing reef; patch reef development is limited largely to the Malindi area in the north. However, an extensive area of *Acropora* banks and other corals occurs between 50 and 80 ft (15 and 24 m) depth south of Malindi, and off Watamu there are a series of submerged reefs from 30 to 80 ft (9 to 24 m) depth. Near Watamu, there are small islets on the extensive reef flat, which are occasionally joined to shore by sand, forming tombolos. On the seaward slope of the fringing reef, submarine terraces have been reported at 8 m and 35 m depth by Brander *et al.* (1971), who give further details for the Watamu reefs.

Hamilton (1975) and Hamilton and Brakel (1984) have shown that the coral diversity of this area is fairly rich, with over 140 species recorded. Coral lists are available from Didham (*in litt.*, 1.11.85).

**Noteworthy Fauna and Flora** Extensive mangroves border Mida Creek. Marine flora and fauna are described in IUCN (1987) and the marine flora at Watamu by Jones (1969).). The marine fauna includes *Tridacna squamosa, Pinctada margaritifera* and many other molluscs. The Wildlife Planning Unit has surveyed the molluscs of the park and surrounding reefs (Samoilys, 1981). A fish list has been compiled by Didham (*in litt.*, 1.11.85) and data of fish in the Watamu area are given in Jones (1969). The Green Turtle *Chelonia mydas* and the Hawksbill *Eretmochelys imbricata* occur in the park (Didham *in litt.*, 1.11.85). Whale Island is a nesting site for Roseate Tern *Sterna dougallii* and Bridled Tern *S. anaethetus* between June and October; other avifauna is described in IUCN (1987).

**Scientific Importance and Research** This area is the largest single expanse of protected reef in the Indian Ocean and is one of the better known reef areas of the Kenyan coast, as a number of university expeditions have used it as a study site (Anon., 1972; Jones, 1969; Keech *et al.*, 1979). It was also visited by the Operation Drake expedition which carried out some work on the reefs (Eagle, 1980). Populations of the urchin *Echinometra mathaei* on the reef have been studied by McClanahan and Muthiga (in press). A government appointed officer is investigating the possibility of establishing a marine research station (IUCN, 1987).

**Economic Value and Social Benefits** Malindi is one of the main recreational centres of Kenya. This is largely due to the existence of the marine parks, visitors to these having increased from about 20 000 a year in 1969 to about 50 000 now (65% visit Malindi Marine Park and 35% Watamu), of which half are Kenyan residents. There are also an increasing number of day trippers from Mombasa hotels. The major attractions are boat trips, water sports, deep sea fishing and coral viewing. The Marine Park Education Centre was opened in 1968 (IUCN, 1987). Malindi has been an important fishing centre for many years and production increased significantly after 1940. It concentrates largely on inshore waters and reef habitats, snappers (Lutjanidae), grunts (Haemulidae) and parrotfish (Scaridae) predominating in quantity and spiny lobsters (Palinuridae), prawns (Penaeidae) and crabs (Brachyura) in value. More recently the fishery has declined, although Malindi is still an important port and receives fishing boats particularly from the Lamu area (Dubois *et al.*, 1985).

**Disturbance or Deficiencies** The major threat to the reefs and the tourist value of the area is increasing siltation from the Sabaki River. This has been observed since the 1930s and 1940s, but apparently caused no serious problems until the early 1960s, when increasing erosion of the land due to uncontrolled cultivation in the Ukambani Hills started to lead to a dramatic increase in sediment loading in the river. Research has shown that these sediments are transported southwards by current and wind action and settle on the reefs at Malindi. Some areas have already been rendered unsuitable for recreation and there has been significant coral die-off, for example at Pillar Reef and on the landward side of North Reef. Beaches have been extended seawards by as much as 200 m by sediments. Since the 1970s the growth in the tourist industry has levelled off and since 1983 has in fact declined; this is considered to be due in part to the poor quality of the water and the dirty beaches. For example, the glass-bottom boat business now slackens between January and March because of poor visibility (DuBois *et al.*, 1985; IUCN/UNEP, 1985).

There is some evidence that increased siltation may have contributed to a marked decline in fishery yield in this area and it may eventually threaten Malindi's role as a port (DuBois *et al.*, 1985). It has been noted that the fish populations are smaller in the Reserves where traditional fishing is still permitted and when proper monitoring is carried out, it may be necessary to introduce quota fishing systems and controls on fishing methods used. Prawn trawlers cause major habitat disturbance in the area and remove all marine life in their paths; the boats are privately owned and there appears to be no means of controlling their activities (Didham *in litt.*, 1.11.85).

There is no pollution from Malindi as the sewage system is closed but there have been oil spills from tankers in deeper waters; the effect of this has not been investigated (IUCN, 1987). There is a potential threat from pollution since the Athi drains the country's main industrial centre around Nairobi. An additional pollution threat (unrelated to the Sabaki problem) comes from the fact that for ten months of the year Malindi is down-current from Mombasa, a large industrial port (DuBois *et al.*, 1985)

Corals and shells have been exploited heavily by visitors and local tradesmen for souvenirs (Evans *et al.*, 1977). Since the establishment of the Parks and Reserves there has been considerable recovery but some poaching persists. The effects of permitted tourist activities such as swimming, sailing and snorkelling have not yet been investigated but there are possible disturbances due to trampling and boat anchorage (Keech *et al.*, 1979).

**Legal Protection** Established in 1968 as a protected area but subsequently the two Marine National Reserves and two Marine National Parks were gazetted under the Wildlife Conservation and Management Act 1976 and Legal Notices 98 and 99. The entire area was accepted in May 1979 as a Biosphere Reserve.

**Management** The complex is managed as a single unit by the Wildlife and Conservation Department. The administration is: The Warden, Marine National Parks, PO Box 109, Malindi, Kenya. There are two assistant wardens, a warden, 45 rangers and 20 support staff. Malindi Marine National Park has its headquarters at Casuarina Point. Watamu has a small land base with an office and staff housing; access to this Marine National Park is mainly through private land belonging to hotels who sell Park tickets.

The National Parks constitute the core areas and the National Reserves form the buffer zone in which traditional forms of fishing are permitted. A management plan for the whole area was prepared by the Wildlife Conservation and Management Department in 1982 (Anon., 1982b) but has not been officially accepted. It identifies three zones: park service zone (land), recreation zone (concentration of water-based recreation) and natural environment zone (coral reef in Malindi Marine National Park and the area of mangroves in Watamu Marine National Reserve).

**Recommendations** Recommendations for improved management of the Parks and Reserves are given in Anon. (1982b) and Jones (1969). There is considerable scope for expanding the administration and visitor facilities. Fishing regulations may need improvement but current practices should be monitored first. It has been suggested that the adjacent section of Arabuko Sokoke forest which contains two Nature Reserves should be included within this protected area (Anon., 1982b).

Although there is little that can be done by the marine park authorities towards decreasing the sediment problem, other agencies have been trying. In 1973, the National Sabaki Committee was formed to try and solve the problem but its recommendations were never implemented. In 1982, the Sabaki (Athi) was added to the jurisdiction of the Tana River Development Authority, created in 1974 to oversee the development of the Tana River, thus forming the Tana and Athi Rivers Development Authority (TARDA). A number of development schemes have been proposed including hydroelectric and irrigation activities. The long-term solution is to deal with the problem at its source. DuBois *et al.* (1985) discuss the infrastructure and type of approach required for the solution of such a complicated issue and emphasise the need for proper monitoring. It has been suggested that a dam could be built on the Athi to decreases the sediment load but this could lead to loss of nutrients in the coastal waters and beach erosion.

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## RAS TENEWI PROPOSED COASTAL ZONE NATIONAL PARK

**Geographical Location** North of the Kipini Tana River Delta on a headland south of the Lamu archipelago; 2°30'S, 40°45'E.

**Area, Depth, Altitude** 35 000 ha: 10 500 ha land and 24 500 ha sea.

**Land Tenure** Government land.

**Physical Features** The area combines marine and terrestrial components and includes extensive coral reefs and several rocky islands. The marine section extends 9 km off shore. Tidal pool development is extensive along the Ras Biongwe area and dunes border the beaches. It has a humid tropical climate affected by monsoon winds (IUCN, 1987).

**Reef Structure and Corals** There are patchy reefs around the islands (Muthiga and McClanahan *in litt.*, 20.1.87).

**Noteworthy Fauna and Flora** Mammals include concentrations of African Elephant *Loxodonta africana* and Topi *Damaliscus lunatus*. Dugong *Dugong dugon* occur in the nearby Tana River estuary. The area is an important flyway and feeding range for Palaearctic and Eurasian birds, particularly raptors and Sylviinae. Migratory seabirds breeding on the rocky islands in July and August include Sooty Gull *Larus hemprichii*, Noddy *Anous stolidus*, Roseate Tern *Sterna dougallii* and White-cheeked Tern *S. repressa*. Tenewi Rocks is the only nesting site in Kenya for the Sooty Tern *S. fuscata*. There are more turtles breeding in this area than on the remainder of the Kenyan coast, including Green Turtles *Chelonia mydas*, Hawksbills *Eretmochelys imbricata* and possibly Olive Ridleys *Lepidochelys olivacea*. Coastal vegetation is described in IUCN (1987).

**Scientific Importance and Research** The area is not considered particularly rich in marine life (Muthiga and McClanahan *in litt.*, 20.1.87) and is mainly of interest for its populations of large animals.

**Economic Value and Social Benefits** The proposed Park area contains three gazetted National Monuments and several ungazetted ruins (*see* IUCN (1987) *for further details*). Visitor facilities include river launch trips from Kipini along the channels and marshes, and an inland viewing track to a waterhole in the forest where elephants can be viewed is proposed. The area is an integral component of the Tana River/Lamu tourist circuit. There is no information on reef use.

**Disturbance or Deficiencies** The silt load in the Tana River, a result of poor land use practices inland, has been estimated at between 9.2 and 14.3 million tons a year and is almost certainly affecting coral reefs in this area (Pertet, 1984a) although it is not known how recent a phenomenon this is (Muthiga and McClanahan *in litt.*, 20.1.87). Poaching of turtles and their eggs occurs along inadequately patrolled shorelines.

**Legal Protection** There are restricted zones during the birds' breeding season.

**Management** None.

**Recommendations** Proposed to the Commission of Lands as a Coastal Zone National Park in 1980 (Pertet and Thorsell, 1981). Management and development proposals include the marking of seaward and land boundaries, provision of two entrance/exit gates, a headquarters, road connections through the Park and viewing tracks. The northern area is to be left undisturbed and there are to be beach and boat patrols. Studies should be undertaken to determine appropriate exploitation of marine resources and the nature and extent of allowable fishing. There are plans for an EEC-sponsored development feasibility study of Lamu

District. A turtle hatchery has been proposed. Implementation of a Kenyatta Settlement Scheme would have a variety of benefits including a game-proof fence, encouragement of a local produce market, improved road access and benefits from increased tourism. The Park would generate local employment.

# KUWAIT

## INTRODUCTION

### General Description

Kuwait is located at the extreme north-western end of the Gulf and has a coastline of 170 km between the latitudes of 28°32'N and 30°N. It is a flat and featureless country within the arid climatic zone (Purser and Seibold, 1973). The northern parts are mostly muddy expanses, formed by the flood waters of the Shatt al Arab, while the southern parts are sandy. Maximum depths rarely exceed 30 m. There are a few islands off shore, the largest of which are Bubiyan and Failaka (Husain, 1976). Three others, Kubbar, Qaruh (Garu) and Umm al Maradim, are smaller and uninhabited with a maximum altitude of 5 m.

Air temperatures commonly reach 46°C during the height of summer and approach 0°C during the winter. Water temperatures over reefs range from 13.2 to 33.4°C. Sustained low water temperatures (less than 17°C) probably occur for about three months of the year and periodically temperatures drop below 15°C (Downing, 1985). Tidal range is 3.5-4m, the largest spring-tides occuring during the day in winter and night in summer. The intertidal zone is therefore seldom exposed in the summer months (Jones, 1986). However, the reef flats of the major reefs dry out regularly at low spring-tides, these periods coinciding with seasons of extreme temperature. Thus, in the summer, reef flat corals face dessication and in the winter may be chilled by near-freezing winds. Turbidity is often high over the reef but can vary by an order of magnitude, the main factors influencing this being the strong currents that flow past the islands, and storms. The water tends to remain hypersaline throughout most of the year. Thus environmental conditions for coral growth are not optimal (Downing, 1985).

Kuwait has the northernmost extension of the western Gulf reefs, and the combined area does not exceed 4 sq. km (Downing *et al.*, 1985). 1:2000 scale charts are being produced depicting coral zones. Isolated corals exist on rocky outcrops on the Southern Kuwait mainland, but reefs are largely restricted to the offshore coral cays. Umm al Maradim is the largest of the islands, with the most extensive reef system and Qaruh is the smallest, but is completely surrounded by coral reef. To the south-west of Umm al Maradim, there is a large break in the reef due to the existence of a sand spit and on Kubbar there is a small break in the reef in a similar location. All the reefs occur in very shallow water, with insignificant coral growth below 15 m depth, the most luxuriant growth occurring above a depth of 10 m. The remaining Kuwaiti reefs are small patch or platform reefs measuring not more than tens of meters (e.g. Dries Rock) or hundreds (e.g. Kasr Mudayrah) in diameter, and a remnant of fringing reef at Ra's az Zawr (Ras al Zoor) (Downing, 1985).

Scleractinian diversity is very low, only about 26 species having been collected. The most important reef builders are *Porites (Porites) lutea, Acropora eurystoma* (?) and *A. valida. P. lutea* is mainly a reef flat coral although it can form tall colonies on the reef edge, some of which extend from 8 m to just below the surface. Some of the patch reefs, such as the Getty Reef at Ra's az Zawr, are almost pure stands of this species. Compared with the Saudi Arabian reefs further south, *Montipora* is notably absent as a reef builder and *Stylophora* is relatively uncommon; it is rarely found at Kubbar but is seen at Qaruh and at Umm al Maradim (Downing, 1985).

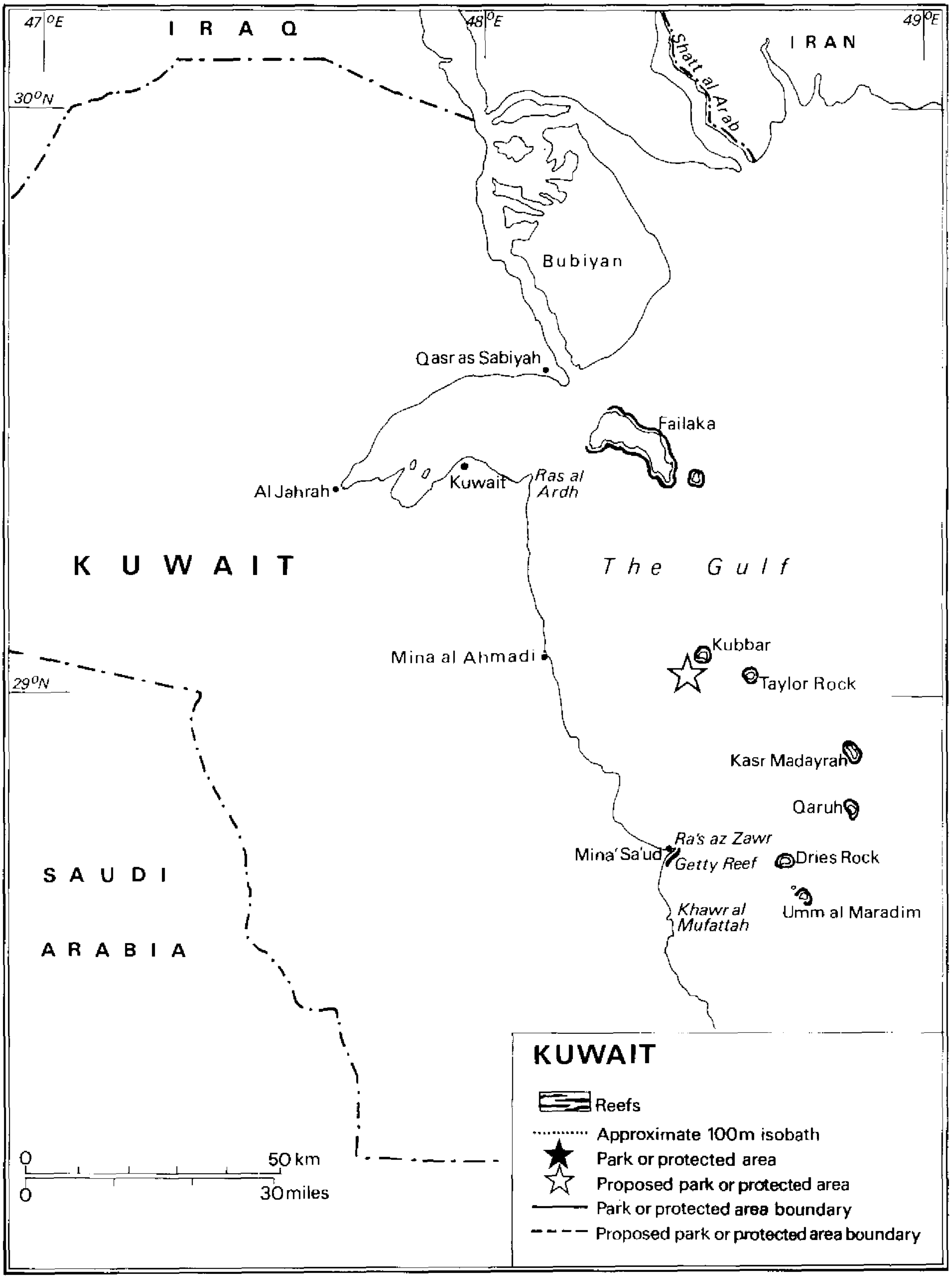
There is a low diversity of fish, about 100 species of teleost having been distinguished to date; 85 species are listed in Downing (1985) and a general description of fish found in Kuwaiti waters is given in Kuronuma and Abe (1972). Marine Mollusca are described by Glayzer *et al.* (1984). The reefs support heavy growths of two species of algae (*Giffordia* sp. and *Colpomenia* sp.) during the winter and spring months which die off as water temperature increases. A general description of Kuwaiti marine life is given in Farmer (1983). Gallagher *et al.* (1984) describe the status of seabirds. Kubbar Island supports breeding populations of several species of tern including Bridled, Lesser Crested, Greater Crested and White-cheeked (*Sterna anaethetus, S. bengalensis, S. bergii* and *S. repressa*). Qaruh has the northernmost turtle breeding area in the western Arabian Gulf, probably for Green Turtles *Chelonia mydas* and Hawksbills *Eretmochelys imbricata*. Turtles also nest on Umm al Maradim and possibly Kubbar (Downing *in litt.*, 20.10.86).

### Reef Resources

There is a limited amount of reef fishing and some commercially important species use the reefs as breeding areas, although the significance of this is not known. There is an artisanal trap fishery based on the Hamoor (a grouper) *Epinephelus tauvina* and the Crimson Snapper *Lutjanus coccineus*, but this is not reef-based (Downing *et al.*, 1985; Morgan, 1985). Mathews *et al.* (1980) briefly describe aspects of fisheries in Kuwait. The Kuwait Institute for Scientific Research has been carrying out studies on the value of artificial reefs to Kuwaiti fisheries (Downing *et al.*, 1985). The reefs are popular recreation areas.

### Disturbances and Deficiencies

Large numbers of the echinoderm *Echinometra mathaei* have caused some damage to the reefs (Barratt and Ormond, 1985). Untreated sewage, industrial effluents and oil result in marine pollution and parts of the coastline have been severely affected (Husain, 1976). Natural oil seepage has been reported in various parts of the Gulf and it is possible that the reefs have developed with crude oil passing over them occasionally (Downing, 1985). However, current development of the oil reserves poses an additional threat. Tanker lanes pass close to Kubbar, Taylor Rock and Kasr Mudayrah. Even a minor spill of crude, such as that discharged with balast, could prove catastrophic if it reached a reef at a very low tide. One such spill was observed to completely encircle Umm al Maradim in April 1984. The last of Kuwait's coastal fringing reef, which probably used to extend as far north as Ra's al Ardh is currently under threat from large scale urban and industrial development south of Ra's az Zawr


47°E
48°E
49°E
30°N
29°N
IRAQ
IRAN
Shatt al Arab
Bubiyan
Qasr as Sabiyah
Failaka
Al Jahrah
Kuwait
Ras al Ardh
KUWAIT
The Gulf
Mina al Ahmadi
Kubbar
Taylor Rock
Kasr Madayrah
Qaruh
Ra's az Zawr
Mina' Sa'ud
Getty Reef
Dries Rock
Khawr al Mufattah
Umm al Maradim
SAUDI
ARABIA
0
50 km
0
30 miles
KUWAIT
Reefs
Approximate 100m isobath
Park or protected area
Proposed park or protected area
Park or protected area boundary
Proposed park or protected area boundary

(Downing, 1985). Military occupation of the small offshore islands may cause damage (Jones *in litt.*, 27.3.83). Nesting terns on Kubbar Island are vulnerable to disturbance, particularly *S. anaethetus*, and there is a certain amount of shooting. Littering of the islands is an unwelcome eyesore and littering and anchor damage are potential problems on the island reefs. General information is given in UNEP (1980).

**Legislation and Management**

There are no marine protected areas. The Environment Protection Council provides an advisory channel on environmental matters to other authorities as well as funds for research. The Ministry of the Interior owns and controls the offshore islands and their associated reefs. There are minimum size limits for a number of fish species, including Crimson Snapper and the Hamoor, and mesh sizes for four different types of net are enforced (Morgan, 1985).

**Recommendations**

A major research project has been under way since 1983 at the Kuwait Institute of Scientific Research (KISR). This aims to provide baseline data on the reefs and reef environment, and management guidelines for their future preservation. Research has covered the collection, photography and identification of corals and reef fish, the monitoring of reef environmental parameters and a detailed hydrographic survey of the major reefs (Downing, 1985). Studies are currently under way with the aim of improving fisheries management (Morgan, 1985).

The Ahmadi Natural History and Field Studies Group, sponsored by the Kuwait Oil Company, has made recommendations to the Government for the establishment of terrestrial reserves and for the outlawing of shooting on the islands. The KISR, in co-operation with the University of Kuwait, is developing plans for the establishment of National Parks and Nature Reserves. The first National Park is expected to cover about 300 sq. km and include the north-western parts of Kuwait Bay, but this does not include reefs (Gallagher *et al.*, 1984).

A proposal has been made to protect the island biota and surrounding reefs of Kubbar (Anon., 1976; IUCN/UNEP, 1985.) and a draft law has been prepared (Downing, 1985). It is hoped that protection will extend to the other coral islands and to Ra's az Zawr, which has rich coral communities (Anon., 1976). The islands require complete protection during the tern and turtle breeding seasons. The reefs are relatively isolated, the furthest occurring 37 naut. mi. (68.5 km) from the nearest centre of habitation, and any enforcement of protective legislation would require a presence on each of the main coral islands.

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# MADAGASCAR

## INTRODUCTION

### General Description

The island of Madagascar covers an area of some 587 000 sq. km, with a coastline of around 4000 km. The climate is predominantly tropical, although the southern part of the island extends below the Tropic of Capricorn. However, there is a wide variety of conditions which are governed principally by a double rainfall gradient, one decreasing from east to west, the other from north to south. Seasonality also increases in these directions, with the dry and cool seasons coinciding in about June-October. This results in eastern and northern parts having a typical wet subequatorial climate, with rainfall exceeding 1500 mm a year and no dry month. Western areas are markedly seasonal with 500 to 1500 mm annual rainfall and seven to eight months dry season. The extreme south is very dry, having erratic rainfall and a near desert environment in the interior. Cyclones are relatively frequent, occurring in the austral summer, with most hitting the island along the north-eastern coast, although they also occur in the Mozambique channel. Seawater surface temperatures range from about 22°C to 28°C (Couper, 1983; Donque, 1972; Jenkins, 1987). The tropical climate of the south-west is described by Derijard (1965).

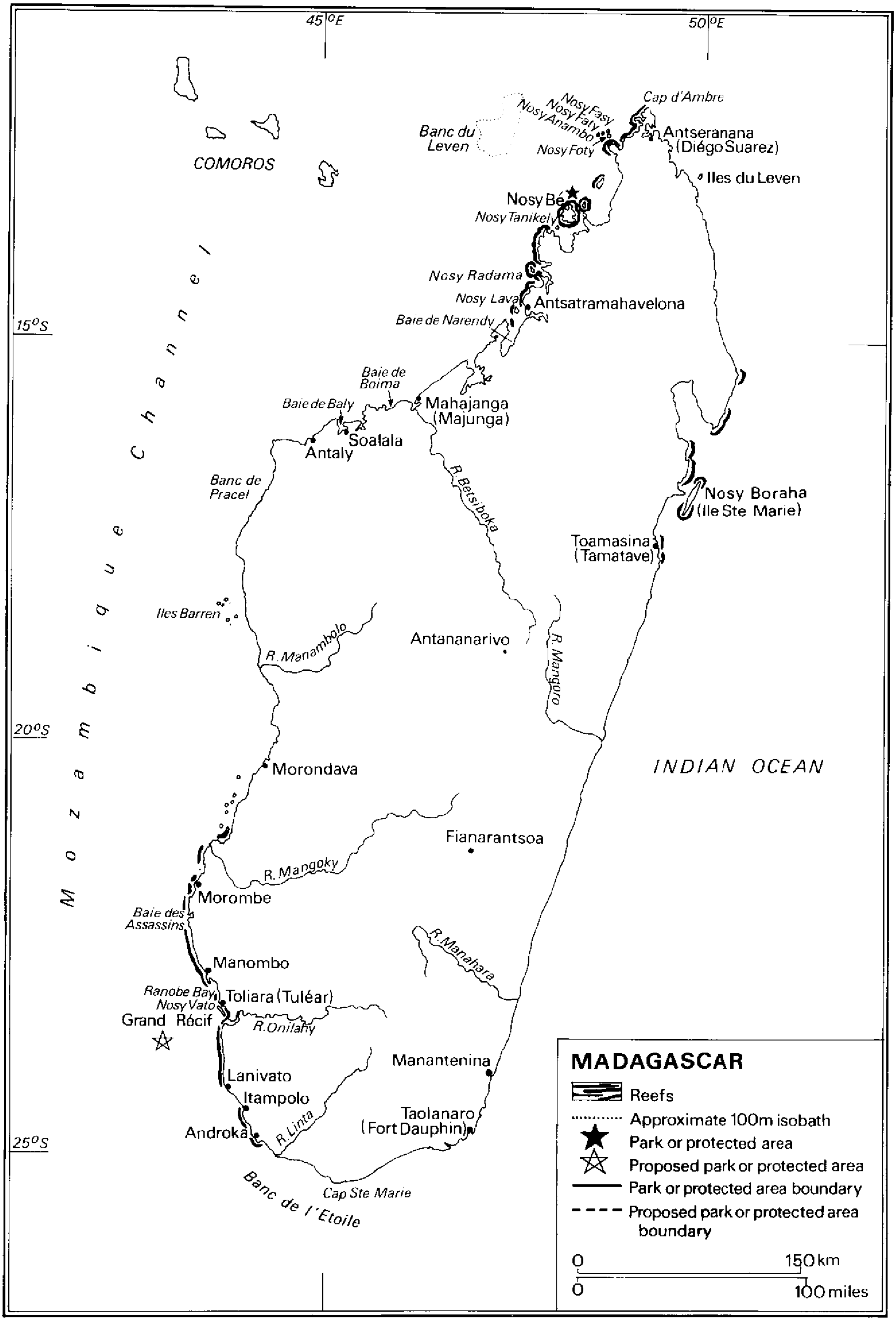
Surprisingly the temperature differences between north and south (between which there is a difference in latitude of 10°) do not appear to have any influence on the richness of the coral fauna. Sixty-three genera of reef-building corals have been found in the Nosy Bé region in the north and 62 at Toliara (Tuléar) in the south. At Toliara, temperatures in the lagoon average 21.5°C in July/August and 30°C in January/February and stony corals disappear at a depth of about 30 m; off Nosy Bé corals extend to depths of 45-60 m. On the east coast high tide level is very low (some 50 cm), while on the west it commonly exceeds 3 m at spring-tide. Western tides are regular semi-diurnal, with low tides at noon and midnight. Currents are predominantly southerly on the east coast, where they are derived directly from the South Equatorial Current. On the west coast they are usually northerly, derived from either the South Equatorial Current as it flows around the south of the country or from a counterflow to the Mozambique Current. Local current patterns tend to be complex because of the large and irregular expanse of many of the reef areas and the large tidal range (Duing, 1970).

Coastal relief is very variable. The continental shelf is very narrow on the east coast, with the 100 m depth contour lying 3 to 5 km off shore and the 1000 m contour 15 to 30 km off shore. In contrast, on the west coast the 100 m contour lies 30 to 80 km off shore and the 1000 m contour, 40 to 150 km. The shelf is notably wide between Cap d'Ambre and Mahajanga (Majunga), between Soalala and Morondava and between Taolanaro (Fort Dauphin) and Androka (Battistini, 1972; Jenkins, 1987; Kiener and Richard-Vindard, 1972). All large river estuaries are in the west and support some 320 000 ha of mangroves, this being probably the largest concentration in the western Indian Ocean. There are a few mangroves on the east coast.

Reefs are extensive and numerous and include good examples of almost all of the main classical reef types. Some of these have been very well studied; the barrier reef at Toliara (*see separate account*) has probably been studied more than any other reef in the Indian Ocean. Others, particularly on the east coast, remain largely undescribed. Most information in the following account is taken from Battistini (1960 and 1964), Clausade *et al.* (1971), Mauge (1973), Pichon (1971a, 1972a, b, 1974a and 1978b) and UN/Unesco/UNEP (1982). Bibliographies of marine studies up to the early 1970s are given in ORSTOM (1973 and 1975). Most research has been carried out at Nosy Bé in the north-west and Toliara in the south-west where the French maintained research stations. Research still continues in these areas, the stations having been handed over to the Madagascan authorities.

Reefs of the east coast are least known. There are rudimentary but extensive fringing reefs bordering a series of coastal dunes behind which runs a chain of shallow lagoons which were once connected to form an inland waterway called the Pangalanes Canal. This was once navigable for about 700 km but much of it is now colonized by herbaceous plants (UN/Unesco/UNEP, 1982). In the north-eastern part around Antseranana there is an emergent reef with a channel up to eight metres deep (Pichon, 1972a). South of Antseranana are two superimposed emergent reefs, the older elevated to 16 m and partly covered by dunes. Nearer the coast, this system becomes fragmented, and has the appearance of a chain of coral islets connected to the land. This series of structures includes the Iles du Leven (Pichon, 1972a) which are bordered at their outer edge by a discontinuous fringe of coral. Such coral reefs are numerous amongst the small islands of the east coast (Rabesandratana, 1984). Further south, Nosy Borah (Ile Sainte-Marie) has fringing coral growth, while in the Toamasina region there is a submerged and fragmented barrier reef. This also has coral growth on the seaward periphery, with a reef flat covered with seagrasses. The sand bar to the south which runs for 700 km is considered by Pichon (1972a) not to have reef formations, although a few coral communities may be found which are isolated and not true reefs.

The west coast has the main reef formations, covering a distance of more than 1000 km (Pichon, 1972a; Rabesandratana, 1985). These are located in the north-west and in the south-west, from the Mangoky delta south to Androka at the mouth of the Linta, separated by a central region with relatively sparse reef growth between Cap Saint-André and the Mangoky delta. In the far north-west, the coast is bordered by emergent fossil reefs up to 10 m above present sea-level. Living fringing reefs are well developed along the mainland coast and around offshore islands, except in the vicinity of deltas and their adjacent bays. Fringing reefs are well developed between Cap d'Ambre and Baie de Narendy; narrow reefs occur between Baie de Courrier and Baie de Bejotaka; small reefs are found off Cap Sebastien. Fringing reef is found on either side of Baie de Ambavatoby and along the west coast of Ampasindanva Peninsula from the Kakamba estuary to the Baie de Rafaralahy. There is a long fringing reef


45°E
50°E
15°S
20°S
25°S
COMOROS
Mozambique Channel
Banc du Leven
Nosy Fasy
Nosy Faty
Nosy Anambo
Nosy Foty
Cap d'Ambre
Antseranana
(Diégo Suarez)
Iles du Leven
Nosy Be
Nosy Tanikely
Nosy Radama
Nosy Lava
Antsatramahavelona
Baie de Narendy
Baie de Boina
Baie de Baly
Mahajanga
(Majunga)
Soalala
Antaly
Banc de Pracel
R. Betsiboka
Nosy Boraha
(Ile Ste Marie)
Toamasina
(Tamatave)
Iles Barren
R. Manambolo
Antananarivo
R. Mangoro
Morondava
INDIAN OCEAN
Fianarantsoa
R. Mangoky
Morombe
Baie des Assassins
R. Manahara
Manombo
Ranobe Bay
Nosy Vato
Toliara (Tuléar)
Grand Récif
R. Onilahy
Manantenina
Lanivato
Itampolo
Taolanaro
(Fort Dauphin)
Androka
R. Linta
Banc de l'Etoile
Cap Ste Marie
MADAGASCAR
Reefs
Approximate 100m isobath
Park or protected area
Proposed park or protected area
Park or protected area boundary
Proposed park or protected area boundary
0 150 km
0 100 miles

between Baie de Ramanetaka and Ansatramahavelona and on the west coast of Nosy Lava. Further south there are a few small isolated reefs, in particular north of the entrance to Baie de Mahajamba, at the entrance to Baie de Majunga (Mahajanga), north-east of Baie de Boina, on either side of Baie de Baly and between the latter and Baie de Antaly. No detailed studies have been made south of Baie de Narendy. Fringing reefs are found around some of the small volcanic islands around this coast such as Nosy Vahila, Nosy Mananono, Tanykely, the Iles Radama and Nosy Saba. Reefs in the Baie de Ramanetaka and around the Iles Radama were described by Guilcher (1956 and 1959) and Guilcher *et al.* (1958). Extensive coral formations are found in some of the bays along the coast where there is little sedimentation, such as Baie de Lotsoina and Baie de Ampanasina. The more exposed reefs, notably some around the island of Nosy Bé in the north-west (*see separate account*), have typical well developed structures, including boulder zones and spur and groove systems. The Baie d'Ambaro, also in the north-west, has been studied in detail because of its rich shrimp stocks (Daniel, 1972; Daniel *et al.*, 1970). Off shore in this area, coral formations occur on the Banc du Leven (Daniel *et al.*, 1972). Octocorals from north-western Madagascar are described by Verseveldt (1973). Reefs at Belo-sur-Mer are described by Solomon (1980).

In addition to these inshore and fringing reefs, there is a rise in the sea floor at the edge of the continental shelf, 10-60 km off shore (Pichon, 1972a) which may be a submerged barrier reef or a cuesta formed during an emergent phase. Much of it lies 5-15 m deep or less in places, but is cut by several channels opposite large river deltas. At its northern end, emergent areas form reefs which support the sand cays of Nosy Anambo, Nosy Faly, Nosy Fasy and Nosy Foty. Elsewhere the surface of the barrier is covered with vast sandy plains and has a coral cover of only 10% in most places. It is likely that the reef is not growing, although no explanation is available for this.

The central section of the west coast has either no reefs or poor fringing reefs, although off shore there are reefs on the Banc de Pracel and around the Iles Barren. The former are spread over 100 km, but only two areas, Chesterfield Island and Nosy Vato, are permanently above water (Pichon, 1972a). The Iles Barren support a greater number of emergent reefs and sand cays and extend over 50 km. It is possible that these are the southernmost extent of the offshore barrier described for the north-west part of Madagascar. Little work has been done on the reefs of the central sector, and further study is required.

Reefs of the south-west sector are well developed and best known (Battistini, 1959; Clausade *et al.*, 1971; Pichon, 1972a, b and 1978b; Thomassin, 1978b; Vasseur, 1981; Weydert, 1973a and b). Fringing reef, barrier reefs and reefs with sand cays are all represented, together with intermediate types. Due to the narrowness of the continental shelf, the reef often changes from barrier to fringing type. Winds and wave energy come from the south-west with enough strength to allow crustose coralline algae to dominate in shallow water. Sand cays are particularly numerous in the northern part of this sector, between the Baie de Assassins and the Mangoky delta. Two kinds of cay exist: those which rest on isolated parts of a barrier well off shore and are separated from it by up to 30 m of water, and those located on a fringing reef situated behind the barrier. Both are adapted to the prevailing south-westerly seas, with a clearly marked succession of spurs and grooves to seaward, an algal flat, a boulder tract and an inner reef flat with corals before the island. To leeward of the islands are seagrass patches, before a leeward slope with spurs and grooves.

From the Mangoky delta there is almost continuous reef to the Onilahy River (Pichon 1972a). In the north of the Baie de Assasins there is a series of small fringing reefs. South of this, the fringing reef is 2-3.5 km wide and extends for almost 80 km. It is interrupted by occasional passages, and contains a channel between it and the shore which is 10 m deep in the north, shallowing to 1.5-5 m in the south, and disappearing at Manombo. South of Manombo, the reefs lie off shore opposite Baie de Ranobe and Baie de Toliara, although between these there is a fringing reef adjacent to the mainland. The reefs of Baie de Ranobe are described by Clausade *et al.* (1971). Opposite Toliara is the Grand Récif which is 18 km long, and up to 3 km wide (*see separate account*). From the Onilahy River, a fringing reef extends southwards almost unbroken for nearly 100 km although it is rather depauperate in comparison with more northern reefs. It varies in width from 0.5 to 3.5 km in the northern part because of a very embayed shoreline, and disappears at Lanivato. A small fringing reef appears south of this at Itampolo and then at Androka. South of the latter, reefs only exist off shore around the sand cay of Nosy Manitsa and the Banc de l'Etoile (Pichon, 1972a). The latter are the highest parts of another submerged barrier reef on the edge of the continental shelf which runs for about 50 km.

Reef fish on the west coast are described by Fourmanoir (1963). Three species of marine turtle definitely nest on Madagascar: Loggerhead *Caretta caretta*, Green *Chelonia mydas* and Hawksbill *Eretmochelys imbricata*; the Olive Ridley *Lepidochelys olivacea* also occurs (Groombridge, 1982; Hughes, 1981). They are exploited for eggs and meat, almost all for local consumption. The most important population is of Hawksbills, of which good numbers still nest mainly in the northern third of the island and in the south-west. However, the population has apparently been reduced to a remnant of its former size by heavy exploitation for the "tortoiseshell" and curio trade; an estimated 2500 are taken annually, mainly by the Vezo people of the south-west. The Dugong *Dugong dugon* occurs principally along the west coast. Although legally protected it is subject to exploitation and has become rare (Jenkins, 1987). Seabirds have been inadequately studied, although ten species nest including several species of tropicbirds *Phaethon* spp., boobies *Sula* spp. and terns (Laridae). They are exploited for their eggs. The only population likely to be of world importance is 4000 *Sterna dougallii* on the coralline island of Nosy Manitsa off the south-west coast which may represent 10-15% of the world population (Cooper *et al.*, 1984). Jenkins (1987) provides summaries of the information available on marine invertebrates, fish and fisheries, seabirds, marine turtles, marine mammals, mangroves and other marine fauna and flora.

**Reef Resources**

A general description of marine and coastal resources is given in Anon. (1985). The main fishery in Madagascar is for prawns; early studies are summarized in Jenkins (1987) and more recent work in this field is outlined in Anon. (1985). The reefs are the basis of a major artisanal fishery. Reef fish are taken in large quantities for local consumption, the main area of exploitation being Toliara, although Morombe is also an important centre of consumption (Rabesandratana, 1985). Over 30 mollusc species are exploited for food including tridacnids, strombids, oysters and a variety of reef species. They are collected by women and children when other animal protein is scarce (Anon., 1985; Rabesandratana, 1984 and 1985). A summary of information on traditional usage of marine molluscs is given in Jenkins (1987). *Turbo marmoratus* and *Trochus niloticus* are collected for export, mainly on the west coast and particularly around Toliara. The current status of the mother-of-pearl fishery is not known. Ornamental shells are collected for export around Androka, Morombe and Nosy Bé (Rabesandratana, 1985; Randrianarijaona and Razafimbelo, 1983) including mother-of-pearl species, the Helmet Shell *Cypraecassis rufa* (12 500-30 000 specimens a year) and many species popular in the ornamental shell trade. The opercula of certain species (*Turbo marmoratus, Fasciolaria trapezium* and *Murex ramosus*) are collected for export as well, and certain marine molluscs are used for the production of lime (Rabesandratana, 1985). The pearl oyster *Pinctada (Meleagrina) margaritifera* and the gastropods *Turbo marmoratus* and *T. imperialis* are exported to Europe for button manufacture, and *Cypraecassis rufa* is sold to Italy for making cameos (Rabesandratana, 1984 and 1985). *Charonia tritonis* has traditionally been collected for use as a trumpet (Jenkins, 1987).

Massive corals such as *Porites somaliensis* were previously used in buildings. Currently, this species is collected in the "Bain des Dames" on the fringing reef at Toamasina, in the south-east, and at Toliara. Corals are also collected for export and for sale to tourists (*see separate account* for Grand Récif). The impact of coral exploitation is not known (Rabesandratana, 1985). The potential use of marine algae is being studied at the Station Marine de Toliara (Rabesandratana, 1985).

Several species of spiny lobster *Panulirus* are exploited: *P. penicillatus, P. burgeri (= P. homarus), P. japonicus* and occasionally *P. ornatus* and *P. versicolor*. The commercial lobster fishery in the 1960s was based mainly on *P. penicillatus* and is described in Charbonnier and Crosnier (1961) and Jenkins (1987) who also give a detailed bibliography. The principal fishing areas were between Cap Ranavalona and Manantenina on the south-east coast. Currently reef-associated lobsters are collected around Morombe for consumption in the capital; the lobster export industry is mainly concerned with stock from the non-reefal areas in the extreme south (Rabesandratana, 1985). The green mud crab *Scylla serrata* is also collected from brackish estuaries, seagrass beds and mangroves, principally on the west coast. The echinoids, *Tripneustes gratilla* and *Heterocentrotus* sp., are eaten locally; the holothurians *Holothuria scabra* and *H. tubulosa* are collected mainly from the region between Androka and the Baie de Mangoky, and are exported to Asian countries. The exporting organisations try to export both large and undersize specimens and the Station Marine de Toliara is currently studying this question with a view to reviewing fisheries laws (Rabesandratana, 1984 and 1985).

Tourism is becoming increasingly important and Nosy Bé and Toliara receive increasing numbers of visitors each year, attracted by reef-related activities such as SCUBA diving (Anon., 1985; Rabesandratana, 1985).

**Disturbances and Deficiencies**

Cyclones cause occasional damage to the reefs (Stirling *in litt.*, 16.4.87). The impact of human activities on the reefs is virtually unknown. A summary of sources of pollution and potential problems associated with these is given in Anon. (1985). Sediment accumulation, as a result of the massive erosion and concomitant soil run-off, affects much of the island and may have an impact on the reefs (Pichon *in litt.*, 1984), but this has not yet been investigated. Deforestation is a continuing problem and about 80% of the land area is now virtually devoid of woody vegetation cover and soil on the eastern two thirds of the island consists largely of thick (10-15 m on average) tropical laterite, making it highly susceptible to large scale erosion (Jenkins, 1987). The port of Mahajanga is now out of action due to the deposition of 100 million cu. m of silt in 25 years. In the north, river deltas have expanded and sediments have reportedly been deposited on beaches and reefs, changing lagoonal current patterns and having potentially adverse effects on local fisheries dependent on reefs and seagrass beds.

Overfishing is reportedly becoming a serious problem, especially on the Grand Récif (*see separate account*). The pearl oyster is becoming increasingly rare (Rabesandratana, 1985), as well as several species popular in the shell trade. Pollution on the western coast, where most reefs occur, appears to be of minor importance at present and dynamiting for fish, which is a common practice in many countries, is not a major threat (Pichon *in litt.*, 1984).

**Legislation and Management**

Five different categories are recognised under the existing legislation: National Parks, Integral Nature Reserves, Special Reserves, and two types specific to forests. National Parks legislation is contained in Decrees 58-07 (28.10.58) and 62-371 (19.7.62). Integral Nature Reserves are sanctuaries mainly governed by Decree No. 66-242 of 30.6.82 in which all human activity is prohibited. Special reserves are regulated by a series of decrees, have less strict protection and are aimed at the conservation of particular species and habitats. Protected areas come under the administration of the Direction des Eaux et Forêts; another department in the Ministère de la Production Animale (Elevage et Pêche) et des Eaux et Forêts is responsible for marine fisheries. According to Randrianarijaona and Razafimbelo (1983), the legislation is not relevant to marine protected areas. There are five areas, designated under a resolution of 23.5.23, in which turtles are protected in as collection is prohibited but this legislation is not thought to be enforced and does not cover the marine environment (Hughes, 1981):

- Nosy Ovambo (Ilot Boise), Diego Province
- Nosy Iranja, Nosy Bé Province

- Chesterfield Island, Morondava Province
- Nosy Trozona, Toliara Province
- Nosy Ve, Toliara Province (two miles south of Toliara and surrounded by coral reef (Direction des Eaux et Forêts et de la Conservation des Sols, 1969))

There are no officially designated marine protected areas, but there is a marine reserve at Nosy Tanikely, off the coast of Nosy Bé, the legal status of which is not known (*see account for* Nosy Bé).

A decree of 23.8.29 imposes controls on collection of pearl oysters, mother-of-pearl shells and sponges. A decree of 27.12.62 establishes a closed season for lobster sale from 1st to 30th April each year, and prohibits exploitation of berried females. A decree of January 1921 stipulates collecting methods for lobsters but it is unlikely that this is enforced. Under a resolution of 24.10.23, turtles may not be taken when they are laying or below a certain minimum size limit. Fishing with explosives is prohibited but it is not known if this is enforced (Randrianarijaona and Razafimbelo, 1983).

**Recommendations**

It is recommended that surveys of the more accessible reef areas: Nosy Bé, Toliara and Nosy Borah, should be carried out to determine their status (Jenkins, 1987) and the establishment of marine parks should be seriously considered (Anon., 1985) particularly at Toliara (*see account for* Grand Récif). Randrianarijaona and Razafimbelo (1983) stress the need to take into consideration the socio-economic factors of any such proposed areas. Multiple use Marine Parks might be suitable, to ensure that the economic benefits to be gained from tourism are not overlooked. Given the intensive collection of molluscs for export for the shell trade, there is probably a need for implementing controls (Rabesandratana, 1985). Recommendations for improvement of the fishing industry are given in Anon. (1985). A series of projects concerning coastal zone management were presented at a conference on Conservation des Ressources Naturelles au Service du Developpement held in Antananavivo in November 1985. These included a study to evaluate coral reef resources, the establishment of the Parc National du Grand Récif de Toliara, and a number of projects relating to fisheries and pollution (Anon., 1985).

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## GRAND RECIF PROPOSED MARINE NATIONAL PARK

**Geographical Location** South-west Madagascar, near Toliara (Tuléar); 23°25'S, 43°40'E.

**Area, Depth, Altitude** Grand Récif is about 18 km long from north to south, and up to 3 km wide. Depths on the seaward slope exceed 50 m.

**Physical Features** The following is derived principally from the work of Clausade *et al.* (1971), Pichon (1962, 1971a, 1972a, 1974b and 1978b), Thomassin (1978b), Vasseur (1981) and Weydert (1973a and b).

The reefs of Toliara, including Grand Récif, are protected from the south-east trade wind by the mainland. South-west winds blow for much of the year but are stronger and more persistant in winter, and are reinforced by thermic wind effects. These raise a rough sea, even in the lagoon area behind the barrier reef. In the absence of this wind, a heavy swell of remote origin can be detected. Cyclones in the Mozambique channel can also create a disturbed sea state for several days. Tides are semi-diurnal, with a maximum range of 3.2 m. This is a lower range than occurs in the north of Madagascar, although it is fairly substantial for coral reef areas. Low spring-tides at noon and midnight have a strong controlling influence on the biota of the reef flat; the tidal amplitude is such that there are strong localized currents during ebb and flow. Rainfall is sparse in this area, but sufficient rainfall in the interior results in permanent rivers and a marked terrigenous component to the sediments near the coast. Surface water temperatures vary seasonally from 22.5 to 27.5°C. Sediments in the reef area are described by Thomassin and Cauwet (1985).

The Bay of Toliara is connected to the sea by two channels, Passe Nord and Passe Sud, which dissect Grand Récif. Nosy Tafara is an islet situated to the south of the Grand Récif. In the southern part of the bay there are three lagoon reefs, Beloza, Dimadimatsy, and Norinkazo, which are separated from the shore by a littoral channel, maximum depth 2 m and 1 km wide. These reefs (about 1000 x 1000 m) are separated from each other by passes about 300 m wide and 4-5 m deep, with strong currents. North of the inner reefs lie two sandstone banks, Mareana and Ankilibe, which have a scattering of isolated coral heads (Clausade *et al.*, 1971). In the south of the bay, there is a fringing reef, 3500 m x 450-1000 m wide, on the west side of the sandy Sarodrana peninsula (Pichon, 1978b).

**Reef Structure and Corals** There have been numerous ecological and descriptive studies of the Toliara reefs (Clausade *et al.*, 1971; Harmelin-Vivien *et al.*, 1982; Jaubert and Vasseur, 1974; Peyrot-Clausade, 1977; Pichon, 1972a, b, 1978a and b; Thomassin, 1978b and 1983; Thomassin and Cauwet, 1985; Vasseur, 1974, 1977, 1981 and 1984; Weydert, 1973a and b). Several distinct zones on the Grand Récif have been described in detail by Pichon (1972a and 1978b). The "frontorecifal ensemble", or seaward reef slope, is very steep but rarely vertical. Scleractinian corals are abundant, extending to at least 30 m depth, depending on local reef profiles and sedimentary conditions. The deep seaward slope, 300-400 m wide, gives way to a gently sloping terrace which drops from 20 to 50 m, with an average depth of 20 m. The terrace is characterized by large furrows at right angles to the reef, the floors of which are sand-filled, with ridges covered with corals. It extends up to the edge of the reef flat which it joins in a short but vertical wall of corals, consisting of a groove and spur system aligned with the coral ridges on the deeper terrace. The grooves are part filled with coral debris; the spurs are constructed of corals and abundant calcareous red algae. Numerous tunnels are formed by grooves which have coalesced at the top. Some of these caverns communicate with the reef flat by blowholes, while others become blocked with sediments. This network of overhangs, grooves and tunnels houses a diverse cryptic community of ahermatypic corals and other sessile invertebrates which has been described by Jaubert and Vasseur (1974) and Vasseur (1974 and 1977).

The spur and groove structures are best developed on parts of the reef most exposed to the south-westerly seas. On the deeper part of the seaward slope below the terrace, coral diversity decreases with depth, and there is a simultaneous decline in abundance (Pichon, 1978b). The dominant coral family is the Pectiniidae, in particular the genera *Echinophyllia* and *Oxypora*; *Pectinia* is less common. Other common genera are the agariciids *Leptoseris* and *Pachyseris*, a *Pocillopora* species and the mussids *Cynarina lacrymalis* and *Blastomussa* sp. Gorgonia and the ahermatypic coral *Dendrophyllia* are also common, with antipatharians and alcyonarians. Coral diversity is greater on shallower parts of the terrace, where species characteristic of the deeper part become less abundant. Common genera are *Acropora, Porites, Lobophyllia* and several faviids. On the buttresses, these species decrease in shallower, more turbulent water, and are replaced by encrusting species from the genera *Pavona, Hydnophora, Montipora* and *Acropora*. The tops of the buttresses support numerous Pocilloporidae, and a high cover of calcareous red algae. In the most exposed parts, *Acropora* is the principal genus, but coralline algae may be dominant, although there is no true algal ridge either here or in any other part of Madagascar (Pichon, 1972a).

The vast plateau of the reef flat of Grand Récif is exposed by a few decimetres at low spring-tides and has been termed the "epirecifal ensemble". On the outer reef flat there is an upper platform of spurs, dominated by crustose coralline algae. Shoreward of this is an outer moat with algae and corals, followed by an outer pavement with encrusting coralline algae but few corals. A boulder tract is then reached, consisting of corals and blocks of limestone deposited by strong sea conditions. This provides the highest elevation on the reef flat, reaching 1 m above the surrounding level. Several corals, zoanthids and algae grow on the boulder surfaces while beneath them is a very rich mollusc, crustacean and echinoderm fauna. Inside this there is an inner moat remaining covered at low spring-tides, which is flat and covered by sandy patches, with many corals whose growth is truncated by the low water level. Microatolls are common, as are groups of corals whose growth is peripheral only. The reef flat at this point is friable and irregular. Corals become less abundant as a third zone of seagrass beds is reached which lie on a slightly raised part, occupying half of the reef flat. Large accumulations of sediments are found here with a typical seagrass-sediment fauna, notably echinoderms (Clausade *et al.*, 1971; Pichon, 1978b).

Behind the Grand Récif, the reef flat gives way to a "postrécifal ensemble" (Clausade *et al.*, 1971; Pichon, 1978b), the reef slope descending to a lagoon floor with a maximum depth of 20 m. Currents mostly run parallel to the shore, and the sediments have an increasing terrigenous component as shore is approached. A variety of seagrasses characterize the area, with abundant coral patches and pinnacles particularly near the reef. These are formed largely by massive faviid corals, with *Acropora*, several foliaceous species,and *Millepora*. Such reefs also occur adjoining the mainland, where their tops support seagrasses which grade into the littoral zone.

Altogether 62 hermatypic coral genera have been reported (Pichon, 1978b). Amongst the corals, the genus *Horastrea* appears to be fairly common (Pichon, 1971b). Thomassin (1969, 1973, 1978a and b) and Thomassin *et al.* (1976) described the sandy bottom communities of the area.

**Noteworthy Fauna and Flora** The marine fauna has been extensively studied. The fish fauna has been described by Harmelin-Vivien (1977 and 1979) and Vivien (1973a, b and 1974). The mollusc fauna on the boulder tracts is described by Thomassin and Galenon (1977). Sponge distribution is described by Vacelet and Vasseur (1977) and Peyrot-Clausade (1981) describes invertebrates on the outer reef slope. Mangroves are found around Saradrano.

**Scientific Importance and Research** More research has been done on the reef morphology and coral communities of the Grand Récif than on any other single reef in the Indian Ocean. Accompanying this is a wide range of marine studies with direct relevance to the reef and its communities, resulting in a very substantial body of detailed literature. For this reason, the reef is of great importance to comparative and temporal studies of reef systems in general. The marine station of the University of Madagascar is situated at Toliara. Up until 1955, the work carried out there was conducted almost exclusively by French researchers (generally from the Station Marine d'Endoume, Marseille). Currently, research is carried out by Madagascans and visiting scientists. Productivity of the reef has recently been studied by Pichon and Morrissey (1985).

**Economic Value and Social Benefits** Commercial harvesting of fish and invertebrates takes place, the former at least, on an increasingly large scale. The Toliara reefs are the main area of exploitation of reef fish, local consumption exceeding 100 tonnes annually. Rabesandratana (1985) provides further details. Prawns are collected on the inner slope of the lagoon where littoral mangroves grow in proximity to the reefs. The Spiny Lobster *Panulirus penicillatus* is collected for local consumption. *Scylla serrata* is occasionally caught on seagrass beds on the Grand Récif. Molluscs collected include *Charonia tritonis, Cypraeacassis rufa,* and *Pinctada (Meleagrina) margaritifera* (Rabesandratana, 1984 and 1985). The massive coral *Porites somaliensis* is collected from the Grand Récif for use in septic tanks and cesspools. Branching corals are collected for sale to tourists in the shell market at Toliara. Corals were exported until at least 1980, when an export figure of 4.1 tonnes was recorded by the Toliara customs office (Rabesandratana, 1985). Shells are exported in large quantities for the ornamental shell trade from the Toliara region, and certain species are considered to be becoming rare (Rabesandratana, 1985). The area has a high potential for tourism, as yet largely unrealized. A French-run hotel caters for the few SCUBA divers who visit the area and an underwater trail has been set up (Pichon *in litt.*, 1983).

**Disturbance or Deficiencies** Overfishing is becoming a serious problem. In 1983 up to 200 boats used the Grand Récif daily whereas in the early 1970s the area was virtually unfished. Populations of benthic fishes have been noticeably depleted, although in 1983 pelagic fish populations were apparently largely unaffected (Pichon *in litt.*, 1983). Fishing is carried out with nets, often with mesh below the legal size, with harpoons and with toxins extracted from plants (e.g. *Euphorbia*). This last method is particularly destructive as it kills indescriminately. The pearl oyster *P. margaritifera* has reportedly been overharvested to the point of virtual extinction and *C. rufa* has become noticeably rarer; concern has also been expressed for *C. tritonis*, of which large numbers, including small specimens, are reportedly on sale in Toliara; minimum size regulations, where these exist are largely ignored (Rabesandratana, 1984). The impact of coral collecting is not known.

**Legal Protection** None.

**Management** None.

**Recommendations** The Grand Récif has been proposed as a Marine National Park and a draft decree for its designation has been drawn up. However, this designation has been refused twice by the Ministry of Animal Production and Forests (Rabesandratana, 1984). The proposal is for the creation of two reserves: an integral reserve, containing the Grand Récif de Toliara (within the area 23°20'-23°38'S, 43°30'-43°42'E), and an adjacent partial reserve, containing the "postrécifal channel", the mangrove area of Saradrano and the reefs fringing the coastline of Barn-Hill Point. The proposal aims to assure conservation of the reef, while developing its potential for scientific research and tourism (both national and international) and managing fisheries resources to allow sustained harvests by local fishermen. Under the proposed decree, access to the integral reserve will be limited to authorized personnel, although this will include tourists accompanied by officials. Licensed artisanal fishermen will be permitted, although fishing will be under strict control (e.g. all underwater fishing and use of toxins, explosives and monofilament nets banned). Access to the partial reserve will be uncontrolled, although again fishing will be controlled and limited to licensed artisanal fishermen. The importance of a local education programme to demonstrate the value of such conservation measures is stressed (Rabesandratana, 1984).

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## NOSY TANIKELY "MARINE RESERVE" AND NOSY BE

**Geographical Location** Islands off north-west coast; 13°20'S, 48°15'E.

**Physical Features** Nosy Bé is a volcanic island on the continental shelf of Madagascar (Battistini, 1960). Its coast is a very embayed low Quaternary plain, and reef flats are found around much of the island. Seaward of the reef flats, the reef slopes are extensive, reaching to at least 20 m depth and sometimes to 45 m. Deeper slopes exist, but these are sedimented (Pichon, 1971a). Nosy Tanikely is a small island, 8 km south of Nosy Bé.

Dominant seas come from the north-west or north-north-west. In winter the south-east trade winds occur but Nosy Bé is protected from these to a great extent by the Madagascan mainland. Rain is infrequent in the cooler season but is abundant in the southern summer which results in a relatively high proportion of terrigenous sediment mixed with the limestone sediments on the reefs. Turbidity is therefore always high. Surface temperatures are relatively stable, ranging from 24° to 29°C. The area is subject to cyclones (UN/Unesco/UNEP, 1982), but the swell is usually weak. The reefs experience a tidal amplitude of 4.2 m (Pichon, 1972a).

**Reef Structure and Corals** The geology of the reefs has been described by Battistini (1960), and their biology by Pichon (1971a and 1972a). The reef communities are characteristic of a low energy regime; fungiids are common and crustose coralline algae are lacking. Approximately 63 coral genera have been recorded (Pichon, 1978b). The most typical reefs are Andilana Reef on the north-west coast, and Amphoraha and Navetsy Reefs on the north coast, which are on the most exposed parts of the island. They have typical spur and groove structures with well developed boulder tracts. On the eastern coast, the reefs Antsatrabevoa, Antafianambitry and Befefiky are exposed only to a local south-easterly breeze with a small fetch. They have extensive reef flats up to 1.5 km wide, a rudimentary spur system, and a small boulder tract both of which are thickly covered with corals with genera such as *Caulastrea*. Other anthozoans and calcareous red algae are not extensive. A seagrass bed of *Thalassodendron ciliatum* and *Syringodium isoetifolium* which forms a 20 m wide, uninterrupted strip just in front of the boulder zone on the outer flats, on a layer of sand of skeletal origin 15-25 cm thick. Seagrass beds are also extensive on the inner parts of the reef flats (Pichon, 1972a). On the west and south-west, the reefs are poorly developed and not very active; reef flats are absent, but their place may be taken by accumulations of broken coral fragments.

The reef slopes extend to only 8 or 10 m depth. A rudimentary spur and groove system is discernible only at low tides on the more exposed reefs (it is absent from sheltered reefs) and appears to be formed from an alignment of corals rather than substantial algal constructions. Coral species are diverse, composed of massive and foliaceous forms and few *Acropora* species. The antipatharian *Eucirripathes* is common. At 8-10 m depth the rough alignments of corals disappear, and the grooves become filled with sediment. On the sedimented slope below the reef slope, communities of the corals *Heteropsammia michelini* and *Heterocyathus aequicostatus* exist, with some *Trachyphyllia geoffroyi*. In general terms, these reefs are regarded as "inner reefs" analogous to the inner reefs of Toliara to the south (*see separate account*) (Pichon, 1972a), while the muddy bottom coral community is analogous to that of a lagoon floor. In this case, the "lagoon" extends from the base of the fringing reefs out to the reefs of an outer barrier which is submerged.

Reef slopes of the outer, submerged barrier formation, which lies to the west, extend deeper than those which fringe the island itself. There are two principal types of slope: gentle slopes (up to 45°) with rich scleractinian communities, notably tubular *Acropora* corals to about 45 m depth, with abundant *Peyssonnelia* and *Halimeda* algae; and near-vertical slopes, which support abundant coral to about 20 m depth, below which diversity is much poorer. At 50-70 m depth, these walls are covered with a fine sediment composed of *Halimeda* fragments.

**Noteworthy Fauna and Flora** Mangroves are abundant in many of the bays and estuaries. The Hawksbill Turtle *Eretmochelys imbricata* is reportedly present although it is not known whether it nests here. Cowries (Cypraeidae) are abundant, and *C. nucleus, C. diluculum, C. onyx, C. oweni, C. lamaki* and *C. chinensis* have been recorded (Magnier, 1981). The Tropicbird *Phaethon lepturus lepturus* breeds on nearby islands (Cooper *et al.*, 1984). Terrestrial fauna is described in Jenkins (1987).

**Scientific Importance and Research** From 1954 to 1975, ORSTOM maintained a research station at Nosy Bé which carried out fishery and other marine studies. Publications of the Station are listed in ORSTOM (1973 and 1975). The Station subsequently became the Centre National de Recherches Oceanographiques (C.N.R.O.). Projects, supported by international and UN funding, are underway on fisheries and physical and chemical oceanography. Pollution has been found not to be a serious problem in this part of Madagascar at present (Pichon *in litt.*, 1983; Stirling *in litt.*, 16.4.87). There is a museum which contains a collection of the local coral fauna and a comprehensive national collection of marine shells. A survey of the reefs at Nosy Tanikely has been carried out recently but the results are not known (Stirling *in litt.*, 16.4.87).

**Economic Value and Social Benefits** Nosy Bé is one of the few important tourist centres in Madagascar (Jolly, 1980; Magnier, 1981); coral reefs are a significant tourist attraction, though it is unclear to what extent their full potential has been developed. Ornamental shells are collected in the Nosy Bé area (Randrianarijaona and Razafimbelo, 1983).

**Disturbance or Deficiencies** Recent cyclones have destroyed much of the fringing reef on the south-west coast of Nosy Bé (Stirling *in litt.*, 16.4.87). *Pinctada margaritifera* has reportedly been heavily exploited, to the point of virtual extinction, having formerly been abundant in the area (Rabesandratana, 1984). The beaches and reefs are reported to have been affected by siltation caused by inland vegetation and forest clearance (Finn, 1983).

**Legal Protection** The 740 ha Réserve Naturelle Intégrale de Lokobé (R.N.I. no. 6) is situated in the south-east corner of Nosy Bé (IUCN, 1987). The coastline forms the southern edge of the reserve (Jenkins, 1987); Pichon (1972a) indicates that at least part of this has a reef front, though it is not clear whether protection extends offshore.

Nosy Tanikely is protected for its terrestrial fauna and the surrounding waters are treated as a Marine Reserve (Magnier, 1981; Rabesandratana, 1984) but its legal status is not known; it may be locally decreed, part of traditional or customary law, or maintained on a voluntary basis by SCUBA enthusiasts.

**Management** Management of Lokobé is described in IUCN (1987) but there is no information on the marine environment. There are no means of enforcing marine conservation regulations.

**Recommendations** Given the potential importance of these reefs to tourism, a survey should be carried out to determine appropriate management.

## INTRODUCTION

### General Description

Peninsular and East Malaysia are situated on the Sunda Shelf in relatively shallow water. The climate is equatorial and modified by the monsoonal wind system. The south-west monsoon prevails from May/June to September/October and the north-east from November to February. Surface water temperatures are around 27°-28°C and there is little stratification with depth. Rainfall is high, usually between 2000 and 4000 mm a year, which causes a seasonal lowering of salinity in coastal waters. Average annual salinity is generally between 32.5 and 34 ppt (Chua and Charles, 1980). A more detailed description of the climate and hydrology of the west coast of Sabah is given in Chua and Mathias (1978).

A general description of the east coast of Peninsular Malaysia is given by Chua (1980a). Shallow (to 15 m depth) fringing reefs are typical but there are also isolated coral patches, most reefs occurring around offshore islands. There is relatively little development along the mainland coast, apart from the area between Trengganu and Chukai on the east coast, and at Tanjong Tuan (Cape Rachado), near Port Dickson, on the west coast. Pockets of coral reefs with no connection to land are reported to the east of Kota Baharu, in the Pulau Redang area (*see separate account*), east of Chukai and east of Pekan (De Silva, 1982b; De Silva *et al.*, 1980; Jothy, 1973). East coast islands have more extensive reefs than those off the west coast. Off Kuala Trengganu, reefs are found around the Pulau Perhentian group, Pulau Lang Tengah and the Pulau Redang group (*see separate account*). South of Pulau Redang, reefs occur around Pulau Bidong Laut, Pulau Belok, Pulau Yu, the Pulau Karah group and Pulau Kapas (Chua, 1980b); the latter have been studied recently (De Silva *et al.*, in press). Further south there are reefs around the Pulau Tenggol group. Reefs lie off the Johor coast around Pulau Seri Buat, the Pulau Tinggi group and the Pulau Tioman group (*see separate account*). Dunn (1970) recorded 18 scleractinians and three other hard corals from reefs around Pulau Aur, south of Pulau Tioman.

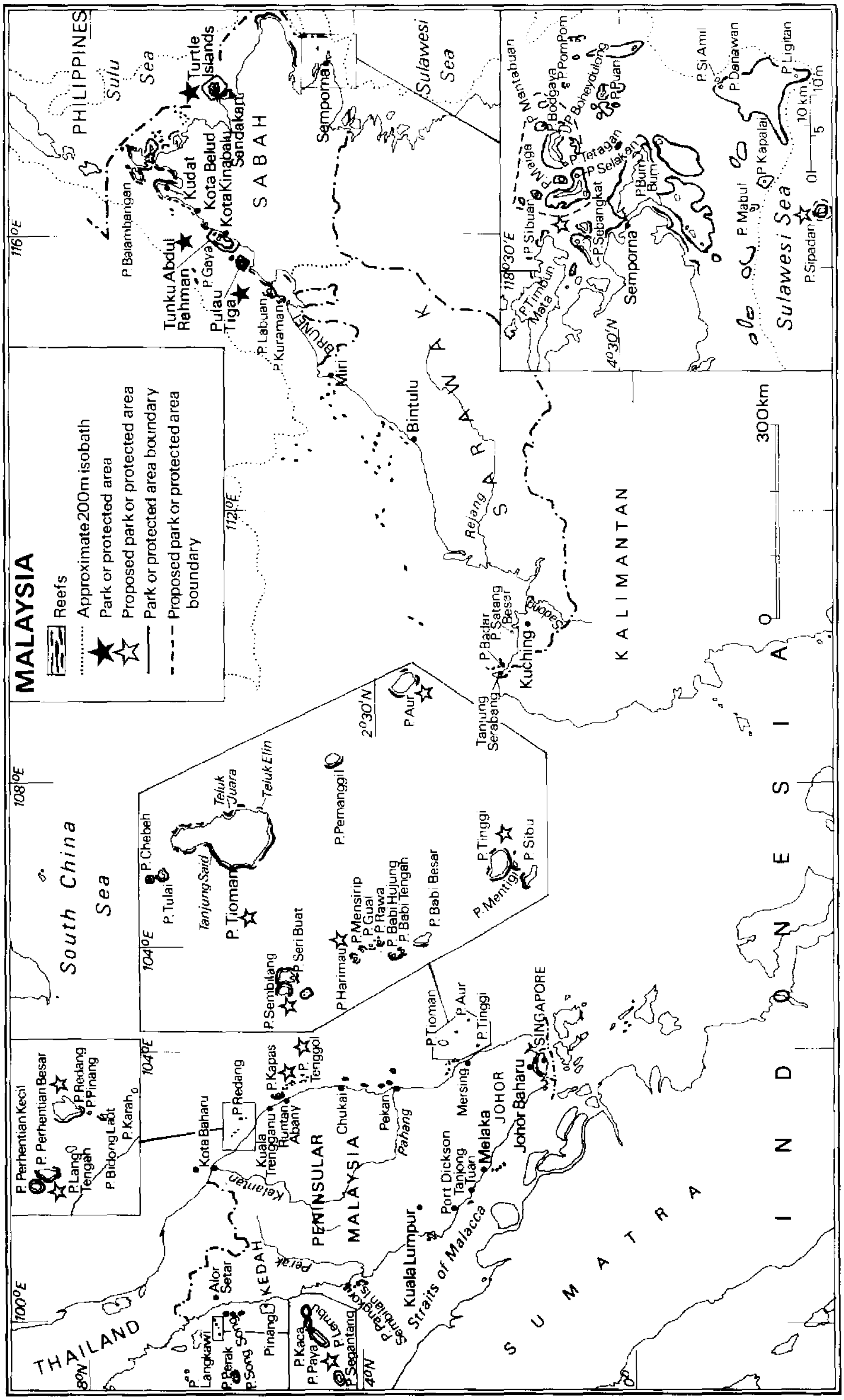
Coral diversity is relatively low on west coast reefs because of turbid conditions and muddy substrates (Chua and Charles, 1980). At Tanjong Tuan, 36 species of hard coral have been recorded and 32% live coral cover was found over an 87 m transect despite the turbid conditions (Goh and Sasekumar, 1980; Liew and Hoare, 1979). Reefs in the Pulau Paya and Segantang group off Kedah, around Pulau Perak and in the Sembilan Islands are described in separate accounts.

In East Malaysia, fringing reefs occur around the 40 or so islands lying in shallow waters off the west coast of Sabah but there is restricted reef development along the adjacent mainland coastline. The Kudat area has about 68 mi. (109 km) of reef, the Kota Belud District has about 40 mi. (64 km), Kota Kinabalu has about 34 mi. (54 km) and the Labuan area about 23 mi. (37 km) (Mathias and Langham, 1978). Reefs extend to a maximum depth of about 17 m. Detailed surveys have been carried out at Pulau Balambangan, islands in Tunku Abdul Rahman Park (*see separate account*), the fringing reef between Tanjong Dumpil and Pulau Mantukud, Tinson Reef, Pulau Dinawan, Everett Reef, Deluar Shoals, Pulau Kalampunian Besar and Pulau Tiga (Tega) (*see separate account*), Pulau Labuan, Pulau Kuraman, Pulau Rusukan Kechil, Pulau Rusukan Besar and Barat Banks (Mathias and Langham, 1978). Many areas were found to be damaged; the best reefs in the Pulau Labuan area were around Pulau Kuraman, Pulau Rusukan and along the west coast of Labuan itself. The best coral reef development elsewhere was around Pulau Tiga, Deluar Shoals and Pulau Balambangan.

In the north-east of Sabah there is little reef development, but reefs within Turtle Islands Park off Sandakan are described in a separate account. Off the south-east coast, there are extensive fringing and patch reefs and a small barrier reef associated with offshore islands. On this coast, the water is clearer and reefs reach 25 m or more in depth. Those in the Semporna area and around the oceanic island, Pulau Sipadan, which lies off the edge of the continental shelf and has corals to depths of over 40 m, are described in separate accounts (Wood, 1979). The only known coral atoll, Pulau Layang-Layang, occurs off the coast of Sabah but there is no information on its surrounding reefs (Ridzwan and De Silva, 1984).

Sarawak lacks diverse coral reefs but coral communities have been recorded in some localities off shore and away from the influence of estuaries and siltation, as at Pulau Satang Besar, off Kuching. A survey of coral communities has been carried out between Tanjung Serabang and Pulau Badar (Walshe and Catsburg, 1979).

Malaysian reefs and their coral fauna have been reasonably well studied. Searle (1956) produced a key to 78 species from Peninsular Malaysia and this work has been updated and expanded by Betterton (1981). Purchon (1965) provides another early list. The coral fauna of East Malaysia is described in Wood (1979) and Wood and Tan (in press). To date, 64 genera of corals have been recorded in Malaysia (De Silva, 1982b). Publications with descriptions and ecological information on specific reef areas include the Straits of Malacca (Pillai and Scheer, 1974), Pulau Paya/Segantang (De Silva, 1982b), Peninsular Malaysia east coast reefs (Chua and Charles, 1980), Pulau Redang (Green, 1978), Pulau Perhentian and Pulau Redang (White, 1986), Sabah west coast reefs (Mathias and Langham, 1978; Wood, 1979) and the Semporna Islands (Wood, 1981). A classification of the reefs is given in Chuang (1977). WWF Malaysia have funded a number of surveys. In Peninsular Malaysia the Universiti Sains Malaysia, Universiti Pertanien Malaysia and Universiti Malaya have been involved in reef research. In Sabah the Universiti Kebangsaan Malaysia have set up a marine research station at Pulau Tiga jointly managed by the Sabah Parks, but there are no other facilities for coral reef research in East Malaysia. Survey methods used in Malaysia are described in De Silva (1984). The Fisheries Department is embarking on a programme of reef research, including work on artificial reefs (Looi *in litt.*, 27.12.86).


MALAYSIA
Reefs
Approximate 200m isobath
Park or protected area
Proposed park or protected area
Park or protected area boundary
Proposed park or protected area boundary
South China Sea
Sulu Sea
Sulawesi Sea
Straits of Malacca
PHILIPPINES
THAILAND
SINGAPORE
S U M A T R A
K A L I M A N T A N
I N D O N E S I A
S A B A H
S A R A W A K
PENINSULAR MALAYSIA
BRUNEI
KEDAH
JOHOR
Turtle Islands
Sandakan
Kudat
Kota Belud
Kota Kinabalu
Tunku Abdul Rahman
Pulau Tiga
P. Gaya
P. Balambangan
P. Labuan
P. Kuramans
Semporna
Miri
Bintulu
Rejang
Kuching
Sadong
P. Badar
P. Satang Besar
Tanjung Serabang
P. Aur
P. Tioman
P. Tinggi
P. Sibu
P. Mentigi
P. Pemanggil
P. Tulai
P. Chebeh
Tanjung Said
Teluk Juara
Teluk Elin
P. Sembilang
P. Seri Buat
P. Harimau
P. Mensirip
P. Gual
P. Rawa
P. Babi Hujung
P. Babi Tengah
P. Babi Besar
P. Perhentian Kecil
P. Perhentian Besar
P. Lang Tengah
P. Redang
P. Pinang
P. Bidong Laut
P. Karah
Kota Baharu
Kelantan
Kuala Trengganu
P. Kapas
P. Tenggol
Runtan Abany
Chukai
Pekan
Pahang
Mersing
Johor Baharu
Melaka
Tanjong Tuan
Port Dickson
Kuala Lumpur
Perak
Alor Setar
Langkawi
P. Perak
P. Song Song
Pinang
P. Kaca
P. Paya
P. Lembu
P. Segantang
P. Pangkor
Sembilan Is.
118°30'E
4°30'N
P. Mantabuan
P. Bodgaya
P. Pom Pom
P. Boheydulong
P. Puan
P. Sibuan
P. Maiga
P. Tetagan
P. Selakan
P. Sebangkat
P. Bum Bum
P. Timbun Mata
P. Si Amil
P. Danawan
P. Ligitan
P. Kapalai
P. Mabul
P. Sipadan
10 km
100°E
104°E
108°E
112°E
116°E
8°N
4°N
2°30'N
0
300km

Coastal fish of west Sabah are described by Chua and Lai (1978). Molluscs of the east coast of Peninsular Malaysia are described by Angot (1980). The Green Turtle *Chelonia mydas* has an estimated population of 4000 females nesting annually in Sarawak and Sabah and is found off Peninsular Malaysia; the Leatherback *Dermochelys coriacea* has 1000-2000 females nesting annually on the 20 km beach at Rantau Abang in Trengganu State; the Hawksbill *Eretmochelys imbricata* is rare off the Perak coast and Pulau Pangkor, but nests frequently on mainland Sarawak and in Sabah is mostly confined to the Turtle Islands Park (*see separate account*); the Olive Ridley *Lepidochelys olivacea* is absent in Sabah but small numbers nest in Sarawak. The Loggerhead *Caretta caretta* may also occur. The Estuarine Crocodile *Crocodylus porosus* is present in the Rejang River of Sarawak and is rare in Sabah where juveniles are taken for stocking farms (De Silva, 1981a; Groombridge, 1982). Mangrove resources of the east coast of Peninsular Malaysia are described by Gong *et al.* (1980); Eong (1982) discusses mangrove conservation issues in Malaysia.

**Reef Resources**

Coral reefs and adjacent waters and habitats are important for both subsistence and commercial fishing. Reef fish comprised 26-29% of the total landings on the west coast of Sabah in 1973 (Mathias and Langham, 1978), and it is likely that some of the fish and shellfish caught for local consumption goes unrecorded. In Trengganu and Pahang, reef fish may constitute 7-11% on average of the fish landed, although in some months the figure may be much higher (De Silva *et al.*, 1980). In west Sabah, reef fish comprised about 25% of the market landings in 1973 and consisted predominantly of snappers (Lutjanidae), pig-face bream (Lethrinidae), fusiliers (Caesiocidae), wrasses (Labridae and Scaridae), rabbitfish (Siganidae), groupers (Serranidae) and grunters (Pomasyidae). Most are caught by handlines or floating gill nets (Chua and Lai, 1978). Fisheries on the east coast of Peninsular Malaysia are described by Jothy *et al.* (1975) and Tan (1980), and on the west coast of Sabah by Chua and Lai (1978) and Chua and Malley (1978) and in a number of other papers in Chua and Mathias (1978).

Six species of spiny lobster (*Panulirus versicolor, P. homarus, P. penicillatus, P. longipes, P. polyphagus* and *P. ornatus*) are caught on coral reefs, usually using spearguns. The fishery on the west coast of Sabah is not currently of great economic importance but has considerable potential. A variety of reef molluscs are collected and used locally for food, and their shells for the ornamental shell trade (Malley and Chye, 1978). The reefs of Pulau Kapas, on the east coast of Peninsular Malaysia, are used as a breeding ground by the commercially important cuttlefish *Sepia pharaonis* (De Silva and Ridzwan, 1983a). Coral is mined for use as limestone in buildings and road construction, particularly on the west coast of Sabah, for example at Pulau Labuan and south of Kota Kinabalu. There is a small trade in curios.

Tourism is one of the fastest growing industries and by the early 1970s was already accounting for over 4% of foreign exchange (Mathias and Langham, 1978). On the east coast of Peninsular Malaysia it is concentrated in the Trengganu and Johor regions (Leong and Siow, 1980a), particularly around the more accessible reefs, such as Pulau Tioman and Pulau Redang. In Sabah, those in the Tunku Abdul Rahman Park off Kota Kinabulu are important tourist attractions, and there is considerable potential for tourist development on Pulau Labuan (Lulofs, 1972; Mathias and Langham, 1978). The value of coral reefs in Malaysia is described in Betterton and De Silva (1979).

**Disturbances and Deficiencies**

*Acanthaster planci* was recorded on a number of reefs in the 1970s, including Pulau Perak and Pulau Redang (De Silva, 1979), Pulau Aur (Dunn, 1970) and Pulau Kapas (De Silva and Charles, in press) but has probably not caused very serious damage, although numbers were locally quite high as at Pulau Redang. Morris (1977) describes the occurrence of *A. planci* on some reefs in Sabah. However, it is suggested that numbers are still high on Malaysian reefs compared with other reefs in the region (Brown, in press). Low tides are reported to have caused damage on the east coast of Peninsular Malaysia (De Silva *et al.*, 1980).

The main causes of reef destruction are removal of coral for building, breakage of coral as a result of fish blasting or trawling close to the reefs, river run-off, and effluent and sewage discharge into the sea (Brown, in press). In Peninsular Malaysia, significant damage has occurred to reefs in the Pulau Paya, Pulau Perhentian, Pulau Redang and Pulau Tioman groups (Ridzwan and De Silva, 1984). Coral mining can only be carried out under licence and living reefs are now generally avoided (Wood, 1977). However, considerable damage has been done in the past, particularly on the west coast of Sabah, for example in the Kota Kinabalu and Labuan areas (Mathias and Langham, 1978). It was estimated that around Pulau Labuan, 20.6 thousand cu. yd (15.7 thousand cu. m) of coral were being removed a year (Lulofs, 1973; Mathias and Langham, 1978). Reefs around Kudat Town were noticeably damaged in the 1970s by coral mining and dynamiting; however, reefs in Kudat and Kota Belud are the least damaged, particularly around Pulau Balambangan.

The use of dynamite and other explosives for fishing is illegal and has been curbed to some extent, but still continues in more remote areas, for example on the Semporna reefs in Sabah (Lulofs *et al.*, 1974; Wood, 1981) and on the southern side of Pulau Kapas, off the east coast of Peninsular Malaysia (De Silva, 1982b). Fusiliers (*Caesio* spp.) are one of the main targets of this method as they normally occur in large shoals and can be killed easily by home-made explosives (Chua and Lai, 1978). There has been a marked decline in fisheries over the last decade, especially in the Straits of Malacca (Rashid, 1982). Populations of marine turtles have declined throughout Malaysia due to development of coastal areas, increased fishing and egg exploitation.

The extent to which reefs have been damaged as a result of sedimentation is unknown. However, noticeable damage has been seen in Peninsular Malaysia (De Silva *et al.*, 1980), off Tanjong Tuan (Liew and Hoare, 1979), around the Pangkor and Sembilan islands (Lulofs, 1977) and in the Pulau Perhentian and Pulau Redang groups (Ridzwan and De Silva, 1984). In East Malaysia, damage has occurred around Kota Kinabalu and in Tunku Abdul Rahman Park (Mathias and Langham, 1978; Wood, 1979). Coral formations on the eastern side of Pulau Satang Besar, in Sarawak, have been killed by siltation (WWF Malaysia, 1985).

Since the 1970s, Malaysia has been an important oil-producing nation, the main oil fields lying off the coasts of Trengganu, Sabah and Sarawak. Drift prediction studies of oil spills for Peninsular Malaysia suggest that Pulau Tioman and adjacent islands would be the most vulnerable to an oil spill. A detailed discussion of the potential impact of this and action required is given in Chua (1980b). Chua and Mathias (1978) provide a similar study for the west coast of Sabah, assessing the biological consequences of an oil spill from the Tembungo Oil Well situated 40 mi. (64 km) off shore; these are considered to be slight but there is a threat from spills from grounded tankers or during loading and unloading in terminals. Additional information on threats to reefs is given in Bong Heang (1982), De Silva (1979, 1981b, 1982a and b), Langham and Mathias (1977), Ridzwan and De Silva (1984) and Wycherly (1969).

**Legislation and Management**

Coral reef management in Malaysia is discussed in De Silva (1984) and De Silva and Ridzwan (1983b). Early publications on marine park requirements and management include Langham (1976) and Lulofs (1972 and 1977). A National Advisory Council on Marine Parks has been set up for the Ministry of Agriculture, consisting of representatives from federal agencies, state governments and private bodies such as WWF Malaysia (Looi *in litt.*, 27.12.86). A Coral Reef Committee has also recently been established.

In Peninsular Malaysia and Sarawak, marine parks could originally be established under the National Parks Act No. 226. (The Wildlife Act of 1972 provides for the establishment of wildlife sanctuaries and reserves (IUCN, in prep.).) In late 1983, the responsibility for marine parks was transferred to the Department of Fisheries and provisions for their establishment and management have now been incorporated into the Fisheries Act 1985. As yet none has been set up, although the waters surrounding 22 offshore islands (*see below*) are earmarked as marine parks within the Fifth Malaysian Plan Period (1986-1990). In the interim, these waters, up to 3 km from shore, have been declared protected areas under the Fisheries (Prohibited Areas) Regulations 1983 (Anon., 1983; Looi *in litt.*, 9.1.87). Marine conservation areas can also be established at State level, under the National Land Code, 1965 (Act 56, Sect. 62).

Management of marine parks in Sabah comes under the National Parks Ordinance, 1962, subsequently replaced by the Parks Enactment Act, 1984). Three marine parks (*see separate accounts*) have been established: Tunku Abdul Rahman Park, Turtle Islands Park and Pulau Tiga Park. Traditional fishing is permitted, but otherwise the marine fauna is completely protected. Management plans have not been prepared but the Parks appear to be well established and effectively wardened. No protected areas in Sarawak include corals.

Jurisdiction over marine living resources is with the Federal Government. The Fisheries Act, 1985, covers all aspects of fishing and prohibits the use of dynamite. Legislation controlling the harvest of turtles has been enacted in the states of Pahang, Trengannu and Kelantan and the turtle hatchery programme is described by Leong and Siow (1980b). In 1986, the export of corals from Sabah was prohibited (CITES, 1986). An artificial reef programme has been under way since 1975 (Rashid, 1982). In the late 1970s, the Sabah Department of Fisheries was investigating the potential of the spiny lobster fishery (Malley and Chye, 1978).

**Recommendations**

The following areas will be established as marine parks over the next decade in Peninsular Malaysia:

- Pulau Paya/Segantang/Lembu/Kaca Islands (*see separate accounts*)
- Pulau Perhentian (Kecil and Besar) and Pulau Lang Tengah
- Pulau Redang (*see separate account*)
- Pulau Kapas
- Pulau Tenggol
- Pulau Tioman group and adjacent islands (*see separate account*)

The islands surrounded by the marine parks will be declared as State Parks and both islands and surrounding waters will be managed by the Fisheries Department (Looi *in litt.*, 27.12.86). A zoning plan and recommendations for the management of the reefs around Pulau Kapas has been drawn up (De Silva *et al.*, in press). There appears to be some general awareness of the need for reef conservation; for example, two of the richest and least-damaged reefs studied on Pulau Tioman were found adjacent to hotels, partly because the managements of these hotels were actively concerned about their condition (De Silva *et al.*, 1980).

Recommendations for the management of coastal resources on the west coast of Sabah, including several of direct relevance to coral reefs, as well as recommendations for dealing with oil pollution, are given in Chua and Mathias (1978). The following areas (*see separate accounts*) have been proposed for protection:

- Semporna Marine National Park
- Pulau Sipadan Marine Reserve

Recommendations for management of coral resources in Sarawak are given in WWF Malaysia (1985). It is suggested that the sale of coral could be prohibited under the Wildlife Protection Ordinance 1958, the effects of land-based activities on corals should be assessed before implementation of such schemes, the enforcement of fisheries legislation should be improved and the harvest of spiny lobsters controlled. Consideration should be given to the establishment of marine protected areas to include corals and appropriate surveys should be carried out. General aspects of coastal zone management in Malaysia are described in Maheswaran (1985) and this issue is an important element of the conservation strategies being prepared for each state with the assistance of WWF Malaysia.

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## PULAU PAYA/SEGANTANG ISLANDS FISHERY PROTECTED AREA AND PROPOSED MARINE NATIONAL PARK

**Geographical Location** Off the west coast of Kedah, Peninsular Malaysia, in the Strait of Malacca; 6°02'N-6°05'N, 99°54'-100°04'E.

**Physical Features** Four islands, Pulau Lembu, Pulau Kaca, Pulau Paya and Pulau Segantang, with fringing reefs.

**Reef Structure and Corals** Corals are reported to be diverse and colourful, especially off the south-west tip of Pulau Paya and the north and north-east sides of Pulau Kaca (De Silva and Ridzwan, 1982). Those at Pulau Paya are described by Rashid (1980).

**Noteworthy Fauna and Flora** No information.

**Scientific Importance and Research** A survey of the reefs has been carried out for WWF Malaysia (De Silva and Ridzwan, 1982). The potential for artificial reefs has been studied at Pulau Paya (Rashid, 1982).

**Economic Value and Social Benefits** The waters around these islands are important fishing grounds for fishermen based in Kuala Kedah (Rashid, 1980). Tourism and recreation are important and the area provides the only clear-water reefs between two established tourist centres, Pinang and Pulau Langkawi (WWF Malaysia, 1984).

**Disturbance or Deficiencies** In recent years, trawlers have been operating around the islands and have caused serious damage to the seabed. Corals have been broken, and nets snagged on rocks. Fish stocks have also been overexploited. Corals are being damaged by explosives and by sedimentation. Increased sedimentation has occurred around Pulau Paya as a result of logging on the island (WWF Malaysia, 1984).

**Legal Protection** Until officially designated as a marine park, the waters surrounding these islands have been declared a protected area under the Fisheries Act, 1985, although fishing by residents is permitted (Looi *in litt.*, 27.12.86).

**Management** No details.

**Recommendations** The establishment of the Paya/Segantang group of islands as a marine National Park was recommended during the 1976 Malayan Nature Society Symposium and more recently in the "Conservation Strategy for Kedah" (WWF Malaysia, 1984). It is planned that a park will be established in 1987, as a multiple-use area (Looi *in litt.*, 27.12.86).

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## PULAU PERAK

**Geographical Location** West of Pulau Penang, Perak, Peninsular Malaysia, in the middle of the Strait of Malacca; 5°41'N, 98°56'E.

**Area, Depth, Altitude** The island has a maximum width of 200 m and is about 12 m high (Pillai and Scheer, 1974).

**Physical Features** A conical rocky island, with the steep slope continuing underwater to a depth of about 50 m. Beyond this is a less steep rubble slope. A consolidated reef framework is absent, but corals grow on the bedrock slope (Pillai and Scheer, 1974).

**Reef Structure and Corals** Corals occur in dense patches on the steep rocks. *Pocillopora* is common and represented by four species, but *Acropora* is conspicious by its absence. Coral diversity is low; 14 species have been found in ten genera (Pillai and Scheer, 1974).

**Noteworthy Fauna and Flora** The Hawksbill Turtle *Eretmochelys imbricata* may nest on the Perak coast but is becoming increasingly rare (Groombridge, 1982).

**Scientific Importance and Research** A brief report on the coral of Pulau Perak is included in Pillai and Scheer (1974).

**Economic Value and Social Benefits** No information.

**Disturbance or Deficiencies** *Acanthaster planci* was reported on the reefs in the 1970s (De Silva, 1979 and 1982a), but it is not known if it caused damage.

**Legal Protection** None.

**Management** None.

**Recommendations** At the 1976 Malayan Nature Society Symposium on the "Role and management of natural parks", a resolution was passed urging the Council of the Malaysian Nature Society to pursue the establishment of a Marine National Park at Pulau Perak. However, this area does not come within the marine park proposals drawn up for the Fifth Malaysian Plan Period (Looi *in litt.*, 27.11.86).

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## PULAU REDANG FISHERY PROTECTED AREA AND PROPOSED MARINE NATIONAL PARK

**Geographical Location** 46 km north-east of Kuala Trengganu, off the east coast of Trengganu, Peninsular Malaysia; 5°47'N, 103°00'E.

**Area, Depth, Altitude** 25 000 ha; reefs extend from sea-level to about 20 m; the highest peak on Pulau Redang is 359 m (Green, 1978).

**Physical Features** Pulau Redang, the much smaller Pulau Pinang, and the seven islets off Redang's eastern shore lie within the proposed park boundary. Pulau Redang is dominated by two ridges separated by a low-lying valley. The east side of the island has sandy beaches while those on the west side are gravelly or have cobble-sized rocks. The small islets are separated from Pulau Redang by relatively shallow water (7-25 m). Coral communities are present off the east coast of Pulau Redang, in areas sheltered from direct tidal and storm infuence, but the most extensive reef development is around the small islets (Green, 1978).

**Reef Structure and Corals** The north and east sides of the islets are characterized by deeper water and have a more diverse coral fauna than that found on the other sides. Large coral heads are present in places and at Pulau Ling there are enormous coral heads (*Porites* sp.), one approximately 40 m in circumference and 10 m high, with a cave at its base. There are also shallow reef flats and coral gardens dominated by *Acropora* spp. and *Montipora* spp. Elsewhere there are steep cliffs, with corals growing on granite bedrock. Fifty-two genera of hard corals are reported from the area (Green, 1978; Green *et al.*, 1979).

**Noteworthy Fauna and Flora** Turtles nest along the north-west coast of Pulau Redang. Reef fish and open water species are plentiful (Green 1978). The WWF survey report (Green, 1978) provides lists of marine algae (57 species), marine worms (36 species), molluscs (82 species) and crustaceans (43 genera).

**Scientific Importance and Research** A general survey has been carried out (Green, 1978; Green *et al.*, 1979) under the auspices of WWF Malaysia and a detailed study of coral zonation and species diversity has been completed (Tan, in prep.). The potential for artificial reefs has been studied at Pulau Ekor Tebu (Rashid, 1982). The area was briefly investigated by White (1986).

**Economic Value and Social Benefits** Indigenous fishermen operate in the area and turtle eggs are collected. There is considerable potential for tourism and recreation (Green, 1979).

**Disturbance or Deficiencies** De Silva (1979) reported the destruction of some reefs at Pulau Redang by *Acanthaster planci*. Ho (1979) found high densities of *A. planci* on reefs south-west of Pulau Lima and Pulau Ekor Tebu, and Warner (1978) reported large numbers at Pulau Perhentian.

By 1970 the shell life was greatly reduced by overcollecting and there was some evidence of blasting and trawling close to reef areas. Protection was enforced but blasting continued around the outer islands in 1975 (IUCN, in prep.). Divers visiting the reefs often use spearguns (Lin, 1981).

**Legal Protection** Maritime waters within eight kilometres from any part off the coast of the island of Pulau Redang have been protected since October 1983 under the Fisheries (Prohibited Areas) Regulations. Under these regulations it is prohibited to collect shells, molluscs or corals from within the protected zone. Fishing is also prohibited, except by licensed fishermen using Pulau Redang as their fishing base (Anon., 1983).

**Management** Fisheries Department.

**Recommendations** At the 1976 Malayan Nature Society Symposium on the "Role and Management of Natural Parks", a resolution was passed urging the Council of the Malayan Nature Society to pursue the establishment of Pulau Redang as a Marine National Park. This proposal was re-emphasized by Green (1978) and it was suggested that an advisory board be set up and a zoning scheme devised. The proposal is also included in WWF (1983). It is planned to establish it in 1987, as a multiple-use area. The Marine Park Centre will include a marine research laboratory (Looi *in litt.*, 27.12.86).

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## PULAU SIPADAN PROPOSED MARINE RESERVE

**Geographical Location** 35 km south of Semporna off the south-east coast of Sabah; the island is adjacent to and claimed by Indonesia; 4°05'N, 118°40'E.

**Area, Depth, Altitude** Total 710 ha, comprising 15 ha of land and 695 ha of coral reef and sea. Corals grow from sea level to 40+ m. The island is low-lying, with an altitude of only a few metres (Wood, 1981).

**Physical Features** Pulau Sipadan lies about 10 km due south of a small barrier reef that marks the edge of the Sabah continental shelf. It represents the peak of a rocky outcrop which rises abruptly from depths of about 600 m. A white sandy beach circles the island and beyond this is a shallow back-reef which is wider to the south and east than to the north. Corals grow on the slopes of the pinnacle (Wood, 1981).

**Reef Structure and Corals** The back-reef consists of rocks, small heads and extensive tracts of branching corals. *Montipora digitata*, *M. fruticosa* and other branching *Montipora* spp. dominate the westerly-facing back-reef. Several low-growing *Acropora* species also occur, including *A. aspera*. The seaward extremity of the back-reef is clearly marked to west, south and south-east by an emergent reef crest. The westerly crest was found to consist mostly of unconsolidated coral fragments (Wood, 1981).

Along much of the shallow fore-reef (1-10 m), coral cover is high and the corals are in excellent condition. There are extensive tracts of branching and plate-like *Acropora* spp. and a variety of other corals, including *Porites*, *Millepora*, *Montipora* and various faviids. Some places along the reef rim, especially on the west side of the island, are more exposed to heavy seas and living coral is replaced to some extent by limestone blocks consolidated with coralline algae (Wood, 1981).

The deeper fore-reef consists of a drop-off characterized by vertical or underhanging rock faces. In places the drop-off begins in water as shallow as 3 m, elsewhere the reef rim curves downwards more gently and the cliff face starts a little deeper. Coral growths on the drop-off, except on some of the shallow, horizontal ledges, are less luxuriant than on the reef rim and there are usually two distinct faunas. The dominant corals on vertical and shaded faces are the non-reef building dendrophylliids, particularly *Dendrophyllia gracilis*. On ledges, encrusting or plate-like corals such as *Pavona* and *Leptoseris* are common (Wood, 1981).

Several species, e.g. *Madracis kirbyii* and *Plesiastrea versipora*, found at Pulau Sipadan have not been reported from other reefs in Sabah (Wood and Tan, 1987).

**Noteworthy Fauna and Flora** The Coconut Crab *Birgus latro* occurs on the island. The most striking feature of the reef is the fish life. Small reef fish are abundant but there are also many medium to large-sized, open water species, including lutjanids and carangids. Sharks are common and at least three species occur in the area (Wood and Wood, 1987). Large antipatharians (black corals) were found on the deep north-facing cliff face (Wood, 1981). There is a substantial Green

Turtle *Chelonia mydas* nesting population (Wood, 1981; Marsh *in litt.*, 18.10.86). Giant clams *Tridacna* occur on the reef flat (George and George, 1987). Terrestrial fauna and flora are described in Wood (1981). The seashore shrub *Messerschmidia argentea* has been found in Sabah only here and in the Turtle Islands Park (Phillipps *in litt.*, 28.2.87).

**Scientific Importance and Research** Pulau Sipadan is the only oceanic island in Malaysian waters and thus of unique importance. A WWF/Sabah Parks survey team visited the island in 1980 and carried out a preliminary study of the reef (Wood, 1981).

**Economic Value and Social Benefits** Residents of neighbouring islands come to Pulau Sipadan to collect turtle eggs, and small fishing boats visit periodically (Wood, 1981). A diving company takes clients on trips to the island (Marsh *in litt.*, 18.10.86).

**Disturbance or Deficiencies** Pulau Sipadan is isolated and the reefs appear to be undamaged. The major disturbance is from neighbouring islanders who come in rotation and collect turtle eggs (Wood, 1981).

**Legal Protection** Pulau Sipadan was declared a Bird Sanctuary in 1933, but is not managed in any way (Wood, 1981).

**Management** None.

**Recommendations** A proposal has been made to establish a Marine Reserve at Pulau Sipadan but this has not been pursued because Malaysia and Indonesia both lay claim to the island and the area is politically sensitive (Liew *in litt.*, 2.28.85). It is recommended that part of the forest, foreshore and reef be designated a Sanctuary Area, partly to protect the turtle nesting area. The rest of the Reserve would be treated as a wilderness area where visitors would be allowed entry by permit. Collection of turtle eggs would be prohibited, and it is suggested that the neighbouring islanders, who claim rights over the island, could act as custodians on behalf of Sabah Parks. Regular patrols to Pulau Sipadan would be made by park rangers based at the Semporna Marine Park (once designated). Pulau Sipadan is totally unsuited to intensive development (Wood, 1981; Wood *et al.*, 1987). The diving company, Borneo Divers, which uses the island is planning to monitor turtle nesting and possibly establish a small hatchery (Marsh *in litt.*, 18.10.86) and is trying to get permission to build some visitor accomodation on the island (Phillips *in litt.*, 28.2.87).

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**PULAU TIGA (TEGA) PARK**

**Geographical Location** Off the west coast of Sabah, south-west of Kota Kinabalu in Kimanis Bay; 5°44'N, 115°40'E.

**Area, Depth, Altitude** Total area 15 860 ha, comprising 607 ha of land, surrounded by 15 257 ha of sea and coral reefs. Reefs extend from sea-level to about 10 m depth; max. alt. 92 m.

**Land Tenure** State-owned.

**Physical Features** Pulau Tiga is the largest island in this group and has three mud volcanoes of over 90 m in height. There is a brackish water lagoon with mangroves, and fine, white sandy beaches on the south side of the island. Two small islands, Pulau Kalampunian Damit and Pulau Kalampunian Besar, lie to the north-east (Wood, 1979).

**Reef Structure and Corals** The best reefs fringe the south-west side of Pulau Tiga. Reefs are less well-developed along the northern and eastern coastlines where the water is more turbid. This is also the case around the two small islands, although reasonable patches of coral occur in places (Mathias and Langham, 1978; Wood, 1979).

On Pulau Tiga, the south-west reef has an extensive back-reef of rubble and sand with low-growing *Pocillopora* and *Acropora* and a variety of encrusting species. The reef rim lies about 1 km from shore and has good growths of coral with some large heads. *Porites* and faviid species are abundant and there are many soft corals, especially where the reef is exposed to heavy south-west swells. Bushy *Pocillopora* and *Acropora* are also common and there are plate-like *Acropora* and *Montipora* colonies. Stands of *Acropora* occur in more sheltered areas, together with *Seriatopora, Merulina* and other fragile forms. The reef descends to a fine sand or silt bottom at about 10 m. Live coral cover on the slope is lower than on the reef rim and there are many patches of rubble and dead coral. Massive, encrusting or foliaceous corals such as *Echinopora, Pavona* and *Pachyseris* are dominant (Wood, 1979).

The central, southern reef has three patches of reef close to the beach, adjacent to a relatively deep water inlet. Corals grow to a maximum depth of 6 m and there are many boulder corals and brain corals. Other faviids, plate corals *Acropora* spp. and lettuce corals *Montipora* spp. are common. The south-east reef has a sandy back-reef, which stretches several hundred metres out to the reef rim, and the fore-reef then slopes fairly gently to a depth of about 10 m. Coral growth on the reef rim is fairly dense, with a good variety of species and growth forms. In sheltered areas there are delicate growths of *Pavona, Montipora* and *Seriatopora* (Wood, 1979). A brief description of the reefs around Pulau Tiga is also given in Mathias and Langham (1978).

**Noteworthy Fauna and Flora** Reef fish are plentiful and varied but most are relatively small (Wood, 1979). Davidson (1982) briefly describes the terrestrial fauna of the islands. Turtles nest on Pulau Kalampunian Besar. Pulau Kalampunian Damit is a well known breeding ground for the seasnake *Laticauda colubrina*. The Lesser Frigate Bird *Fregata ariel* roosts at night in the *Pisonia* trees that dominate the island. The Megapode *Megapodius freycinet* and the Pied Hornbill *Anthrococeros coronatus* are abundant on Pulau Tiga. Small flocks of the rare Pied Imperial Pigeon *Ducula bicolor* and the Nicobar Pigeon *Caloenas nicobarica* regularly visit Pulau Tiga which is exceptionally rich in wild fruit trees (Phillipps *in litt.*, 28.2.87).

**Scientific Importance and Research** Descriptions of the reefs, with diagrams and maps are given in Mathias and Langham (1978) and Wood (1979). The Universiti

Kebangsaan Malaysia (Sabah Branch) will be setting up a marine research station on Pulau Tiga, under the jurisdiction of the Board of Trustees of Sabah Parks. The research station will include two laboratories, two hostels, staff quarters and a central area for other facilities (Liew *in litt.*, 2.28.85).

**Economic Value and Social Benefits** The islands are uninhabited but fishing is carried out around the reefs. The area has good potential for recreation and tourism, but is at some distance from Kota Kinabalu and so only accessible by medium-sized boats (Mathias and Langham, 1978).

**Disturbance or Deficiencies** The reefs are considered by Mathias and Langham (1978) to be among the least damaged along the west coast of Sabah.

**Legal Protection** The Park was established in June 1978. Collection of fauna and flora is prohibited, except by local fishermen using approved methods.

**Management** Administration: Sabah Parks, P.O. Box 10626, 88806, Kota Kinabalu, Sabah. A ranger station has been established on Pulau Tiga. A jetty has been constructed and a nature trail has been developed on the island (Davidson, 1982; Phillipps *in litt.*, 28.2.87). There is no zoning system.

## PULAU TIOMAN AND ADJACENT ISLANDS FISHERY PROTECTED AREAS AND PROPOSED MARINE NATIONAL PARKS

**Geographical Location** Off Johor, east coast of Peninsular Malaysia.

**Physical Features** The main islands in this area are: Pulau Tioman, the largest and westernmost, and P. Tulai and P. Chebeh lying to the north-east; a group between P. Tioman and the mainland, comprising P. Sembilang and P. Seri Buat; a group further south, comprising P. Hariman, P. Mensirip, P. Gual, P. Rawa, P. Babi Hujung, P. Babi Tengah and P. Babi Besar; and the most southerly group, P. Tinggi, P. Mentingi and P. Sibu. The north, north-east and east sides of many of the islands have rocky cliffs dropping straight into deep water; reefs may be found in sheltered bays but in general these coasts are too exposed for coral growth apart from a few encrusting species and a larger number of soft corals. The west, south-west and south sides are sheltered from the north-east monsoon and have sandy beaches with well-developed fringing reefs (De Silva *et al.*, 1980).

**Reef Structure and Corals** The reefs have been studied by De Silva *et al.* (1980). A total of 170 species of hard coral in 47 genera was recorded. Most of the reefs were at depths of 1-7 m, a few reaching 15 m. In general, they gave way to sand without the development of a sharp gradient on the reef front and did not extend beyond 150 m from the shoreline. The coral fauna varied little between islands, the main genera being *Acropora, Montipora, Pocillopora, Porites, Psammocora, Pavona, Fungia, Echinopora, Favites, Goniastrea, Platygyra, Galaxea* and *Millepora*. On Pulau Tioman, the best reefs were found in front of Hotel Merlin-Samudra, south of Tanjung Said on the west coast, and at Teluk Eliu, on the south-east coast. Reefs around P. Sembilang and P. Seri Buat were in good condition, and there were a number of rich and interesting reefs in the P. Rawa group, particularly near the Rawa Safari Tourist Centre.

**Noteworthy Fauna and Flora** Molluscs around the islands are described by Angot (1980). Hawksbill *Eretmochelys imbricata* and Green Turtles *Chelonia mydas* occur in the islands (Leong and Siow, 1980b).

**Scientific Importance and Research** A detailed study of the islands and their surrounding waters was carried out in 1978/9 to investigate the potential risk of marine resources to an oil spill. The results are given in Chua and Charles (1980).

**Economic Value and Social Benefits** The reefs are very important to the local fishery. Reef-related recreational facilities are concentrated on the islands off Mersing which is a focus for tourists. In 1980, 37 boats were operating out of Mersing, taking tourists to the islands. There are two main hotels (De Silva *et al.*, 1980).

**Disturbance or Deficiencies** There is some collecting of marine curios but this has little impact on the reefs. On Pulau Tioman, Pulau Tulai and several reefs in the P. Rawa group, a number of heavily damaged reef areas were found, which were considered to be due to fishing with explosives by foreign fishermen. Sedimentation and freshwater run-off may have affected the reef at Teluk Juara on Pulau Tioman and a reef at Pulau Mensirip (De Silva *et al.*, 1980). Although oil pollution has not affected the reefs yet, drift prediction studies of oil spills from the existing oil rigs off Trengganu suggest that Pulau Tioman and adjacent islands would be most at risk (Chua, 1980b).

**Legal Protection** Until marine parks are officially designated, the waters surrounding these islands up to 3 mi. (5 km) from shore have been declared protected areas under the Fisheries Act, 1985, although fishing by residents is permitted (Looi *in litt.*, 27.12.86).

**Management** Tourists and fishermen are actively discouraged from damaging the reefs and some of the best reefs in 1980 were located directly off the main hotels (De Silva *et al.*, 1980).

**Recommendations** Marine National Parks are to be declared in this area within the next decade (Looi *in litt.*, 27.12.86).

## SEMBILAN ISLANDS

**Geographical Location** Off the west coast of Perak, Peninsular Malaysia, in the Strait of Malacca; 4°02'N, 100°33'E.

**Area, Depth, Altitude** Reefs extend from sea-level to a maximum depth of 15 m.

**Physical Features** A group of small islands. The water is muddy and corals grow in patches rather than being consolidated into reefs (Pillai and Scheer, 1974).

**Reef Structure and Corals** Corals tend to occur in patches on a rubble or sandy/muddy bottom. A collection made at three stations yielded 11 species in 9 genera (Pillai and Scheer, 1974).

**Noteworthy Fauna and Flora** The Hawksbill Turtle *Eretmochelys imbricata* occurs occasionally on nearby Pulau Pangkor (Groombridge, 1982).

**Scientific Importance and Research** A brief report on the corals of the Sembilan Islands is included in Pillai and Scheer (1974).

**Economic Value and Social Benefits** No information.

**Disturbance or Deficiencies** Some of the reefs were reported to have been damaged by silt in the 1970s (Lulofs, 1977).

**Legal Protection** None.

**Management** None.

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## SEMPORNA PROPOSED MARINE NATIONAL PARK

**Geographical Location** About 25 km north-east of Semporna, off the south-east coast of Sabah; 4°38'N, 118°46'E.

**Area, Depth, Altitude** Total 29 664 ha, comprising 1234 ha of islands, 28 430 ha of coral reefs and sea. Reefs extend from sea level to a maximum depth of 25 m. The highest peak is at 455 m on Pulau Bodgaya.

**Land Tenure** The islands are claimed by local people under native titles and long-standing legal rights (Wood, 1981).

**Physical Features** The three central islands, Pulau Boheydulong, Pulau Bodgaya and Pulau Tetagan in Darvel Bay comprise part of a now flooded volcanic caldera. The rest of the volcano rim is submerged and marked by an arc of coral reefs enclosing a lagoon about 8 km across. Fringing reefs have developed around the outside of these islands, and to some extent within the lagoon. The topography of Pulau Boheydulong and Pulau Bodgaya is dramatic and rugged. In many places the hillsides drop steeply to the sea, leaving only a narrow wave-cut shingle terrace. Sandy beaches are best developed on the western and eastern shorelines of Pulau Boheydulong (Wood, 1981).

Outside the main complex are a number of other islands and reef systems. To the west of Pulau Tetagan is an atoll-like formation which is probably based on a submarine extension of the main volcano. Pulau Sebangkat and Pulau Selakan mark the edge of the L-shaped atoll, and both are low islands of raised coral limestone. The three other outlying islands, Pulau Sibuan, Pulau Maiga and Pulau Mantabuan, are also low-lying with sandy beaches, and each is surrounded by a fringing reef. There are two patch reefs within the proposed park boundary (Wood, 1981).

**Reef Structure and Corals** The outer, non-lagoonal reefs show a great deal of variety in relation to the extent of back-reef, presence or absence of an emergent reef crest, extent of fore-reef and degree of slope on the fore-reef. In some cases the back-reef is narrow, with the reef front close to the shore, in others it is wider and may take the form of a shallow lagoon (e.g. on the north side of Pulau Bodgaya). Growth of hard and soft corals is restricted and the bottom consists mostly of sand and loose or concreted rubble. The reef flat at the seaward edge of the back reef consists of a mixture of corals, limestone blocks, sandy patches and pools. Coral growth varies from sparse to dense. Some areas are characterized by clean white sand interspersed with small to large coral outcrops or micro-atolls. The larger outcrops often consist of stands of branched *Montipora* or *Porites*, the micro-atolls are *P. lutea* and *P. murrayensis*. Elsewhere, luxuriant growths of low-profile corals have developed, usually on north- and east-facing reefs, and in many cases the dominant coral is *Acropora*, occurring in dense thickets or extremely flat plates (Wood and Tan, 1987).

The relatively exposed north- and north-east-facing reefs generally have a fairly steep profile. Coral cover along the shallow fore-reef is high and there is a good variety of species and growth forms. The deeper fore-reef tends to be dominated by massive, encrusting or plate-like corals. Faviids, pectinids, *Galaxea*, *Physogyra* and *Plerogyra* are common. Below a depth of about 20 m on these steeper, more exposed reefs, coral outcrops tend to be more widely spaced and separated by gulleys or rubble-strewn areas. Low-profile corals such as pectinids, mussids and fungiids are common and there are also tall colonies of the tree coral *Tubastraea micrantha*. The more sheltered south and south-west facing reefs tend to have a gentler profile. The shallow fore-reef supports a rich variety of hard and soft corals, often with *Acropora* spp. dominant. Corals on the deeper fore-reef tend to be branched, e.g. *Acropora*, or leafy, e.g. *Turbinaria*, but massive and encrusting forms also occur (Wood, 1981).

The Bodgaya lagoonal reefs are relatively shallow (15 m) and moderately sloping. Vertical development is reasonably good, due to the presence of coral heads on the reef rim and slope and an abundance of large coral colonies. Massive and foliaceous types, e.g. faviids, *Porites*, *Turbinaria*, are particularly common, but there are also tracts of branching corals such as *Acropora*, *Montipora* and *Heliopora*, especially in shallow areas (Wood, 1981). Some of the reefs in Darvel Bay are described by Morris (1978).

A total of 191 scleractinian species have been recorded from the Semporna Islands and Pulau Sipadan (Wood and Tan, 1987).

**Noteworthy Fauna and Flora** There is a rich and varied fish fauna around the islands and at least 200 species have been recorded (Wood, 1981; Wood and Wood, 1987). There is also a rich invertebrate fauna, the major groups being sponges (130 species), cnidarians excluding hard corals (100 species), crustaceans (30 species), molluscs (73 species), echinoderms (83 species) and ascidians (21 species). *Tridacna squamosa*, *T. maxima*, *T. crocea* and *Hippopus hippopus* were seen on all reefs surveyed. *T. gigas* also occurred but was rare (George and George, 1987). Terrestrial fauna and flora are described in IUCN (in prep.).

**Scientific Importance and Research** A WWF/Sabah Parks survey team visited the area in 1980 (Wood, 1981).

**Economic Value and Social Benefits** The Semporna reefs are extremely important fishing grounds for islanders and local people, and for Bajaus who visit from northern Sulu. Most of the Bajaus who lived on the islands have moved to the mainland and there is only one significant village (300 people) on Pulau Selakan. Pulau Sebangkat has a mixed population of 1000 people, many of whom come from the Philippines. The nomadic Bajaus who traditionally live on boats had eight mooring sites in the park in 1980 (IUCN, in prep.). A variety of molluscs are collected, both for food and for sale as curios. Crabs, holothurians and sea urchins are also utilised for food. Japanese Pearl Oysters *Pinctada* sp. are cultivated at the Kaya Pearl Company, which is based on Pulau Boheydulong. The majority of the pearls are exported directly to Japan. Local people visit Pulau Sibuan at weekends, primarily to swim and picnic. The Semporna Islands as a whole have considerable potential for tourism (Wood, 1981), but this is negligible at present due to lack of hotel accommodation in Semporna and public transport to the islands (IUCN, in prep.).

**Disturbance or Deficiencies** There is a growing population of settled and nomadic people within and around the proposed park area. The central islands of Bodgaya and Boheydulong are being used increasingly for agriculture, and mangrove is exploited for firewood and timber. Pigeons, hornbills, Bearded Pigs *Sus barbatus* and Sambar Deer *Cervus unicolor* are hunted. Megapodes and their eggs are also taken (Wood, 1981).

Molluscs, including *Tridacna, Strombus, Lambis*, cowries and other gastropods appear to be heavily exploited. Dynamite, poisons (derris and ladtang), spears and harpoons are used to catch fish, as well as lines, nets and traps. Dynamite is particularly damaging, and patches of broken coral were seen on a number of the reefs. Sewage, other organic matter and non-biodegradable rubbish from the Pearl Farm is deposited in the lagoon, and there is also pollution from the black, viscous tar which is used to coat the grids to which the oysters are attached. The Pearl Farm camp is unsightly and their operations encourage boat traffic within the lagoon (Wood, 1981).

**Legal Protection** Pulau Boheydulong was declared a Bird Sanctuary in 1933, but this was revoked in 1978 and the status of Pulau Bodgaya as a Forest Reserve was revoked in 1977. Thus the fauna and flora are unprotected.

**Management** None at present.

**Recommendations** It is recommended that the Bodgaya-Boheydulong complex and outlying islands and reefs are established as a Marine National Park. However, it is proving difficult to implement this proposal because of numerous claims for land compensation by local people (Liew *in litt.*, 28.2.85). A zoning scheme is proposed, based on a progression from local pressure and involvement in the western and central parts of the proposed park area to isolation and reduced pressure in the east. Four zones are proposed. 1. A Local Use/Buffer Zone will permit residents to maintain a livelihood through traditional but regulated fishing; visitors could use the zone for recreation, but commercial exploitation of marine resources would be prohibited. 2. A Central Park Zone would have special scenic and scientific value and would incorporate a range of sublittoral habitats; fishing and other exploitation of marine resources would be prohibited. 3. An Intensive Use Zone, based on Pulau Boheydulong, would include administrative, research and visitor facilities 4. A Wilderness Zone to the east would be subject to minimal disturbance and could be considered almost as a Reserve; entry to this zone would be by special permit only and the fauna completely protected. General recommendations concerning proposed management and management policy are included in Wood (1981) and Wood *et al.* (1987).

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## TUNKU ABDUL RAHMAN PARK

**Geographical Location** Off shore from Kota Kinabalu on the west coast of Sabah; 5°55'-6°04'N, 116°0'-116°05'E.

**Area, Depth, Altitude** Total area, 12 160 ha; comprising 1736 ha land (islands) and 10 324 ha sea and coral reefs. Reefs extend from sea-level to 17 m. Pulau Gaya is the highest island, with a maximum altitude of 92 m.

**Land Tenure** State-owned.

**Physical Features** The Park includes most of Pulau Gaya, the whole of Pulau Sapi, Pulau Mamutik, Pulau Manukan, Pulau Sulug and the surrounding sea. The islands all have white sandy beaches interrupted by rocky coastline and, on Pulau Gaya, a small mangrove area. Fringing reefs occur around the islands and there are two small platform reefs lying north and north-east of Pulau Mamutik (Liew, 1981; Wood, 1979). The calmest conditions are from February to May, but the area is relatively sheltered and can be visited during much of the year (Wood, 1979).

**Reef Structure and Corals** On Pulau Gaya the best developed reefs are on the south-west coast and around Bulijong Bay at the western end of the north coast. The back-reef typically extends seawards about 50-150 m to where the reef rim is reached and is sandy, with patches of seaweed, rubble and some living coral. The fore-reef slope is fairly gentle and corals grade into mud or sand at depths of up to 17 m. The shallow reef rim and upper slopes are often dominated by branched and massive *Porites* and staghorn or plate *Acropora*, but a wide variety of other species occur. Live coral cover is 100% in places, especially on the sheltered south coast reefs. Reef slopes below about 6 m support fewer species, with *Porites* spp., *Montipora* spp. and faviids commonest. Live coral cover is often less than 25%, and there are extensive areas of dead coral, as well as patches of sand and rubble. The headlands on the north side of the island are fairly rocky and exposed, as is the entire west-facing coast. As a result a luxuriant fringing reef has not developed and the seabed is characterized by bedrock, boulders, rubble and coarse sand. Live coral cover is about 25% and massive types such as *Favia* spp., *Favites* spp. and brain corals are characteristic (Wood, 1979).

Pulau Sapi has a shallow, sheltered reef adjacent to the main beach at the eastern end of the island, dominated by *Seriatopora spp.*, *Acropora* and *Porites* (staghorn and branched), and *Pavona* spp. The rest of the coastline is fairly exposed and the fore-shore rocky. Subtidally there is a gradually shelving platform consisting of boulders and rounded or encrusting coral colonies on a rocky or coarse sand base. Soft corals are common. The reef rim at about 6-10 m is ill-defined, but marked in places by *Porites* heads. The reef slopes away gently and live coral cover is low (Wood, 1979).

The fringing reef is poorly developed along the north coast of Pulau Manukan, which has a shelving rocky platform with patches of sand and encrusting or massive corals. Off the west coast a shallow, sandy back-reef leads to the reef rim, where live coral cover is between 10 and 50%. In places, rubble has been concreted into ramparts separated by channels. Small coral colonies, especially *Pocillopora* spp., grow on the ramparts. The reef descends fairly gently and coral cover on the slope is low, generally less than 10%. There is a small reef off the central part of the south coast but this has only isolated patches of living coral. The south-eastern end of the island has an extensive and shallow back-reef, leading to a narrow reef rim and gentle slope. The coral on the rim is reasonably dense and varied but live cover is noticeably less on the slope (Wood, 1979).

At Pulau Mamutik, the sea-bed off the exposed west and north coast consists of sand, boulders and a few coral outcrops. A shallow, sandy back-reef at the north-eastern end of the island leads to a narrow reef rim. Coral here is dense and in good condition with abundant staghorn and plate *Acropora* as well as many other species. There is a gentle slope to about 6 m depth, where the coral becomes sporadic, giving way to sand. At the southern end of the island is a small, steep reef which is dominated by branched *Porites* spp., with some *Heliopora coerulea*. The reef ends on sand at about 5 m depth (Wood, 1979).

The best developed reef of Pulau Sulug lies on the south side of the island, stretching in a wide arc across the bay. To the shoreward side is a shallow back-reef of sand, small boulders and isolated coral colonies. It is separated from the fore-reef in places by a sandy moat in which grow a few seaweeds and soft corals. The shallow reef rim is extensive and the corals are densely packed and varied. *Acropora, Montipora, Seriatopora, Pocillopora* and *Echinopora* (branched) are particularly common, with the former two genera exhibiting a wide range of growth forms. The reef rim drops down at about 45° to fine sand at a depth of 6-14 m. Live coral cover on the slope is less than 10% and there is much less diversity than on the reef top. Considerable areas are covered with rubble or algal-encrusted limestone (Wood, 1979).

The platform reefs lying north and north-east of Pulau Mamutik are each less than 200 m in diameter. The reef top is at about 3-4 m depth and the slope drops off at about 45° to a sandy, silty bottom at about 12 m. There is a good deal of variation in species composition, growth form and density of living corals across the top and around the rim of the reef, due in part to differing sea conditions. The northern and western sides of the reef tend to be especially open to heavy seas at certain times of year. As a result, banks of coralline algae have built up and coral cover is relatively low, but colonies tend to be fairly robust. There are many faviids and small, low clumps of *Acropora, Pocillopora, Seriatopora, Galaxea*, and encrusting/lobed *Montipora*. The most luxuriant coral lies to the south-east of the southern reef where there are extensive tracts of staghorn *Acropora*, foliaceous *Montipora* and *Millepora* spp. Coral cover and species diversity on the reef slopes is low (Wood, 1979). The reefs of Pulau Gaya and associated islands were also described by Lulofs (1973 and 1974), and Mathias and Langham (1978) surveyed a patch reef south of Pulau Gaya and reefs around Manukan and Sulug.

**Noteworthy Fauna and Flora** Turtles have been seen around the islands but apparently do not nest there. Shallow reef areas support good populations of reef-associated fish species, especially damselfish (40 species), anemonefish (6 species) and butterflyfish (17 species) (Wood, 1979). Terrestrial fauna and flora are described in IUCN (in prep.). Pulau Gaya is covered by typical coastal dipterocarp forest with a few species not recorded elsewhere. The other four islands have all been logged in the past and are covered with old secondary vegetation, planted coconut groves and fruit trees (Phillips *in litt.*, 28.2.87).

**Scientific Importance and Research** The reefs of the Tunku Abdul Rahman National Park have been surveyed by Wood (1979) as part of a WWF Malaysia Project; earlier surveys were carried out by Lulofs (1973 and 1974).

**Economic Value and Social Benefits** Traditional, subsistence fishing is carried out within the Park, but the major activity in the area is tourism and recreation. The Park is close to Kota Kinabalu, the capital of Sabah, and is a popular attraction for both local people and visitors from overseas. The beaches are attractive and the shallow reefs ideal for snorkellers and SCUBA divers. There are several nature trails on the islands (Liew, 1981).

**Disturbance or Deficiencies** The major problem appears to be siltation as many of the corals on the reef slope are dead but intact, covered with algae and/or silt. The reefs have evidently deteriorated relatively recently, possibly as a result of land clearance and agricultural activities in the vicinity of Kota Kinabalu (Wood, 1979). In past years, reefs have been damaged as a result of coral mining and fish bombing (Lulofs, 1973; Wood, 1979). A patch reef south of Pulau Gaya was reported by Lulofs *et al.* (1974) and Mathias and Langham (1978) to have been seriously damaged in several places by dynamiting. These activities have decreased since the Park was established and in 1979 corals were recovering (Liew, 1981; Wood, 1979) although dynamiting is reported to have continued (Marsh *in litt.*, 26.11.86). The reef at Pulau Sapi has been damaged by visitors treading on the coral and is littered with rubbish (Wood, 1979). There have been some problems with people attempting to settle on Pulau Gaya (Davidson, 1982).

**Legal Protection** The Park was established in May, 1974 and extended in 1979 to include Pulau Mamutik, Pulau Manukan and Pulau Sulug. The marine fauna and flora are completely protected and it is strictly prohibited to collect any living or non-living plants, animals, shells, rocks, etc., without prior permission from the Park

Warden. Recreational fishing is permitted, with hook and line, provided no more than two hooks per line are employed. Traditional fishing using lines or non-static traps is allowed, provided a permit is obtained from the Park Warden.

**Management** Local administration: Sabah Parks, Box 10626, 88806, Kota Kinabalu, Sabah. The Park Headquarters are sited on Pulau Manukan and there are shelters on this island, Pulau Sapi and Pulau Gaya and a resthouse on Pulau Mamutik. There is no zoning system (Liew, 1981) or management plan (Liew *in litt.*, 28.2.85). There are about 13 miles (21 km) of nature trails on Pulau Gaya, including a raised broadwalk through the mangrove swamp. An interpretive booklet has been produced by Sabah Parks (Liew, 1981). A glass-bottom boat operates in the Park at weekends and on public holidays.

**Recommendations** Sabah Parks are hoping to employ a full-time marine biologist to help set up underwater trails and an education and interpretive programme (Liew *in litt.*, 28.2.85).

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## TURTLE ISLANDS PARK

**Geographical Location** Off the east coast of Sabah, north of Sandakan Harbour; 6°9'-6°11'N, 118°03'-118°06'E.

**Area, Depth, Altitude** Total 1736 ha, comprising 18 ha land, 1 722 ha sea and coral reef. Corals extend from sea-level to a maximum depth of 12 m. Altitude of the islands does not exceed 5 m above sea-level.

**Land Tenure** State-owned.

**Physical Features** There are three small islands in the group, Pulau Selingaan, Pulau Gulisaan and Pulau Bakkungaan Kecil. Each has a predominantly sandy shoreline, the sand extending to back-reef areas. Fringing reefs are present around each island and there is a platform reef between Pulau Selingaan and Pulau Bakkuagaan Kecil. The water in the area tends to be relatively turbid, because of the proximity of the islands to the coast of Sabah, where many rivers and streams drain into the sea. The outer island, Pulau Bakkungaan Kecil, lies in water about 26 m deep, the inner island, Pulau Gulisaan, in water only about 8 m deep (Wood, 1979).

**Reef Structure and Corals** The reef front and slope is about 300-600 m from the shore, tending to be closest around the outer island. There is little coral development on the south side of the islands and most on the east sides. Around Pulau Gulisaan the reef is extensive but shallow. There are large tracts of coral rubble or silt-covered substrate and live coral cover is probably less than 10%. *Heliopora coerulea* and massive *Porites* are dominant but there is little or no *Acropora*. Pulau Selingaan east reef has higher coral cover, up to 50%, and is dominated by encrusting or massive corals. Faviids such as *Goniastrea* are common, together with mussids and *Porites*, but colonies tend to be relatively small. Amongst the foliaceous/encrusting types, *Montipora, Merulina* and *Turbinaria* are the most common. There are also clumps of *Acropora*. Reef condition improves towards its northern end, where the bottom of the slope is at a depth of 10 m (Wood, 1979).

The back-reef around Pulau Bakkungaan Kecil consists of clean coral sand interspersed with small rocks and corals, especially faviids. Faviids and *Porites* dominate the west-facing shallow fore-reef, but on the reef slope coral cover is fairly low. The slope is relatively steep, flattening out at about 12 m. Coral cover on the east-facing shallow fore-reef is higher and the dominant coral is *Acropora*, mostly plate-like forms but also some staghorn species. Low-growing soft corals are also abundant, and taller bushy types are present on the reef slope, together with a few sea fans. In contrast to the branched *Acropora* spp., most colonies are massive, with *Porites*, faviids and mussids the most common (Wood, 1979).

The platform reef has a flattish sandy top only a few metres deep. Around the reef rim are scattered boulders and heads of a reasonable size, and other rounded, massive or encrusting corals. There are also low, branching types such as *Acropora* plates, and clumps of *Acropora, Pocillopora* and *Heliopora*. Coral cover is as much as 50% in places (Wood, 1979).

**Noteworthy Fauna and Flora** The Green Turtle *Chelonia mydas* and Hawksbill Turtle *Eretmochelys imbricata* nest on the islands all the year round, although numbers are declining. The clam *Tridacna crocea* is relatively common. Fish are plentiful and include various commercial species such as lutjanids, serranids and carangids (Wood, 1979).

**Scientific Importance and Research** A description of the reef, with diagrams and maps is given in Wood (1979). Three turtle hatcheries have been established on the islands with mariculture tanks to hatch and rear the hatchlings before releasing them back to the sea. During 1970-78, 8980 adult turtles were tagged (De Silva, 1981a).

**Economic Value and Social Benefits** Local people and tourists visit the islands to watch the turtles coming ashore to lay their eggs.

**Disturbance or Deficiencies** Considerable disturbance has occurred in the past from collection of sand and coral for building, dynamiting for fish and trawling close to the island. Turtles have been frightened away by fishing fleets anchoring close to the islands and using bright lights at night. These activities have been curbed since the islands were given protected status (De Silva, 1981a). There is still a danger of sedimentation as a result of soil erosion from logging and agricultural activities on the adjacent Sabah mainland (Wood, 1979).

**Legal Protection** The fauna and flora are totally protected. The islands were designated as Game and Bird Sanctuaries in 1972, and the Park was created on 1.10.77 in order to incorporate the marine component.

**Management** Local administration: Sabah Parks, Sandakan, Sabah. Wardens are present on the island.

# MALDIVES

## INTRODUCTION

### General Description

The Maldives form the central and largest part of the Laccadive - Chagos Ridge which extends southwards from India to the centre of the Indian Ocean and consists entirely of a chain of low atolls and associated coralline structures. Although its territorial area is considerable, extending 867 km in length, only a small part is dry land (about 300 sq. km). The atolls rise from a submarine ridge which is generally only 270-380 m deep but descends to more than 1000 m between the main group of atolls and Suvadiva and Ari in the south. There are 1302 islands (Anon., 1984), although published estimates vary from 1200 (islands which are emergent at high tide with some vegetation) to 2000. The majority are small with only nine being larger than 2 sq. km and three of these being larger than 4 sq. km. Areas with vegetation cover vary from a few square metres to 6 sq. km. Maximum altitude is no more than 5 m above sea-level (Munch-Petersen, 1982 and 1985).

Gardiner (1903-1906) describes climate and geology; more recent data has been provided by Munch-Petersen (pers. comm., 1985) and Stoddart (1966d) and a brief overview is given in UNEP (1986). The climate is tropical oceanic with little temperature variation either during the day or throughout the year. Humidity is high (rarely below 70%) and the air has a high amount of salt. Wind speeds are generally moderate and only the northernmost atolls are affected by cyclones, devastating effects occurring only about once in 100 years. Rainfall increases from under 2000 mm a year in the north to about 2300 mm in the south, with most in May, September and October and least from January to March (60-70 mm a month). Freshwater is found on most islands in the form of freshwater lenses floating at 1-3 m depth on the salt water below and a number of islands have fresh and brackish lakes (Munch-Petersen pers. comm., 1985). Tides are mixed, mainly semi-diurnal, and have small ranges throughout, from about 0.7 m in the north to nearly 1 m in the south (Couper, 1983; Stoddart, 1971). Water temperatures are fairly constant throughout the archipelago, ranging from 25 to 29°C. In January, the northern part of the archipelago has westerly surface currents, driven by the Indian north-east monsoon, and the southern part has easterly currents due to the Equatorial Counter Current. In July, most of the archipelago has easterly currents due to the Indian south-west monsoon, although this is weak and may be absent from the southernmost atoll, Addu.

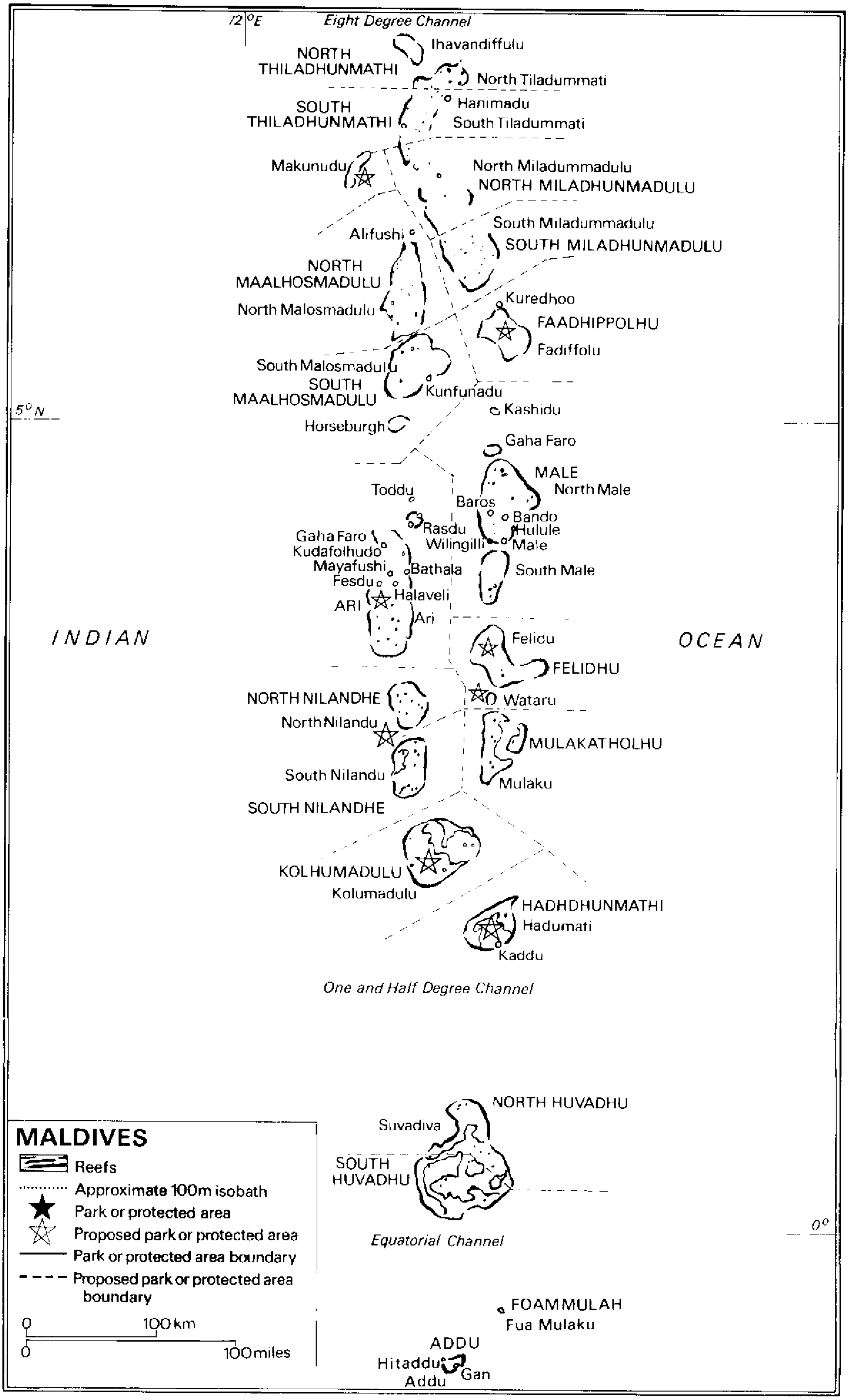
General descriptions of the archipelago are given in Gardiner (1903-1906), Fosberg (1957), Stoddart (1966b), Salm (1975) and Munch-Petersen (1982). The atolls lie on longitude 73°E, from which no part is further than about 80 km, and from north to south are named as follows (official Maldivian name, Maldivian code in brackets, common English names of areas within the atoll, alternative spellings in brackets):

- *North Thiladhunmathi* (Haa Aifu)
  Ihavandiffulu (Ihavandhippolhu, North Tiladummati)
- *South Thiladhunmathi* (Haa Dhaalu)
  South Tiladummati, Makunudu (Makunudhoo)
- *North Miladhunmadulu* (Shaviyani)
  North Miladummadulu° (North Maladummadulu)
- *South Miladhunmadulu* (Noonu)
  South Miladummadulu° (South Maladummadulu)
- *North Maalhosmadulu* (Raa)
  North Malosmadulu**°, Alifushi (Powell Island)
- *South Maalhosmadulu* (Baa)
  South Malosmadulu**° (Greater Baa), Horsburgh° (Goifurfehendu)
- *Faadhippolhu***° (Lhavyani)
  Fadiffolu**° (Laviyani)
- *Male* (Kaafu)
  Kashidu (Kaashidhoo), Gaha Faro (Gaafaru), North Male**° (Maale Uthurruburi), South Male° (Maale Dhekunuburi)
- *Ari* (Alifu)
  Toddu (Thoddoo), Rasdu** (Rasdhoo), Ari** (Alif)
- *Felidhu* (Vaavu)
  Felidu° (Vaav), Wataru (Vattaru)
- *Mulakatholhu* (Meemu)
  Mulaku° (Meem)
- *North Nilandhe* (Faafu)
  North Nilandu° (Faaf, Nilandhe Uthuruburi)
- *South Nilandhe* (Dhaalu)
  South Nilandu° (Dhaal, Nilandhe Dhekunuburi)
- *Kolhumadulu* (Thaa)
  Kolumadulu°
- *Hadhdhunmathi* (Laamu)
  Hadumati° (Laam, Hadummathi)
- *North Huvadhu* (Gaafu Alifu)
  Suvadiva (north)**° (Huvadu)
- *South Huvadhu* (Gaafu Dhaalu)
  Suvadiva (south)**° (Huvadu)
- *Foammulah* (Gnaviyeni)
  Fua Mulaku (Fuah Mulah, Mulakku)
- *Addu* (Seenu)
  Addu**° (Seen)

** = described in separate account; ° = described by Gardiner (1903).

The northernmost extremity of the Maldives (7°07'N) is on Ihavandiffolu and the southernmost (0°42'S) on Addu; the westernmost and easternmost extensions are Makunudu Reef (72°33'W) and Foththeyo Island Reef, Felidhu (73°45'E). Ihavandiffulu is a simple atoll. North and South Tiladummati and North and South Miladummadulu to the south make up a single, large, elongated atoll called Noon-Shaviyani divided administratively into four units. Purdy (1981) suggests that the evolution of the atolls is causing lateral expansion inwards towards the Maldive's inner sea and that ultimately they may coalesce, which may account for the complex structure of this northern part of the chain.

Further south, the atolls form two chains, one on either side of the submerged limestone ridge, which continue for nearly half the length of the archipelago, to Kolhumadulu and Hadhdhunmathi. Many of these are classical in structure, with a typical rim of reef flat surrounding a lagoon, but others, notably Ari, are surrounded by a ring of faroes. Where the double chain terminates near the south, deep channels separate the



72°E
Eight Degree Channel
Ihavandiffulu
NORTH THILADHUNMATHI
North Tiladummati
Hanimadu
SOUTH THILADHUNMATHI
South Tiladummati
Makunudu
North Miladummadulu
NORTH MILADHUNMADULU
South Miladummadulu
SOUTH MILADHUNMADULU
Alifushi
NORTH MAALHOSMADULU
North Malosmadulu
Kuredhoo
FAADHIPPOLHU
Fadiffolu
South Malosmadulu
SOUTH MAALHOSMADULU
Kunfunadu
Kashidu
5°N
Horseburgh
Gaha Faro
MALE
North Male
Toddu
Baros
Bando
Hulule
Rasdu
Male
Wilingilli
Gaha Faro
Kudafolhudo
Mayafushi
Bathala
South Male
Fesdu
Halaveli
ARI
Ari
INDIAN
OCEAN
Felidu
FELIDHU
NORTH NILANDHE
Wataru
North Nilandu
MULAKATHOLHU
South Nilandu
Mulaku
SOUTH NILANDHE
KOLHUMADULU
Kolumadulu
HADHDHUNMATHI
Hadumati
Kaddu
One and Half Degree Channel
NORTH HUVADHU
Suvadiva
SOUTH HUVADHU
MALDIVES
Reefs
Approximate 100m isobath
Park or protected area
Proposed park or protected area
Park or protected area boundary
Proposed park or protected area boundary
0 100 km
0 100 miles
Equatorial Channel
0°
FOAMMULAH
Fua Mulaku
ADDU
Hitaddu
Gan
Addu

atolls from North and South Huvadhu and Addu. There are a few small islands on more or less isolated platforms, such as Foammulah (probably a raised atoll) in the south, and several on the main platform which are intermediate between atolls and faroes, such as Gaha Faro, north of Male.

Atolls vary from open structures with numerous islands, faroes, patches and knolls in the atoll lagoon and around the rim (e.g. Male and Ari) to almost closed structures with few lagoonal knolls and patches, and a ribbon reef structure and/or a series of islands along the peripheral reefs (e.g. Addu, Rasdu and Horsburgh). Faroes are ring-shaped reefs, each with their own sandy lagoons (50 ft (15 m) deep), and are separated by channels which may be as deep as the central lagoon floor (60-180 ft (18-55 m)). They generally have a rim of living coral of both branching and massive species. Patches rise to 40 m above the lagoon floor and are usually capped with wave-breaking corals; there may be a small lagoon. Knolls rise 20 m above the lagoon floor and do not reach the surface. Some of the atolls have lagoonal islands which are simple knolls with sloping sides of about 45° and emergent surfaces capped with vegetation (Fosberg, 1957; Kohn, 1964b). The sides often support profuse coral growth (over 60% coral cover to at least 20 m) and are indistinguishable in biological terms from the sides of normal, submerged knolls (Reefwatch data; Sheppard pers. comm., 1985). Along the latitudinal gradient of atolls from the Lakshadweep Archipelago (Laccadives) in the north, through the Maldives to the Chagos in the south (spanning over 18°) there is a broad trend of deepening lagoons (Scheer, 1972) and steadily increasing coral generic diversity (Sheppard, 1981) from north to south. Lists of corals from the Maldives are provided by Wells and Davies (1966), Rosen (1971) and more recently by Pillai and Scheer (1976); Stoddart (1984) states that 66 genera of scleractinians have been recorded, of which 55 are hermatypic.

Stoddart (1966c) provides a bibliography of work in the Maldives. Early studies include Agassiz (1903) and Gardiner (1902 and 1903-1906), the latter being a detailed account of an expedition in 1899 and 1900 with descriptions of the marine and terrestrial fauna and flora. Sewell (1936a and b) described Horsburgh and Addu in considerable detail. Fosberg (1957) provides a general account of the Maldives. The "Xarifa" Expedition visited the Maldives in 1957-1958 and reported on fish (Klausewitz, 1972a, b, 1973 and 1974; Klausewitz and Eibl-Eibesfeldt, 1959) and corals (Franzisket, 1964; Hass, 1962; Pillai and Scheer, 1976), some 80 papers resulting from this expedition. Popular accounts of the expedition are given in Hass (1965) and Eibl-Eibesfeldt (1966 and 1982). A brief description is given in Kohn (1964a). Scheer (1971 and 1972, 1974 and 1978) describes reefs on Addu and atolls in the central and northern part of the archipelago, especially on Rasdu. Stoddart (1966a) describes a 1964 expedition to Addu (*see separate account*). General information on the Maldives is given in Moutou (1985a and b). North Male has been visited by several diving expeditions in recent years, and observations from some of these supplied by Reefwatch (University of York) and Sheppard (pers. comm., 1985) have been used in this section. In 1984, the Ministry of Fisheries opened a Marine Research Section with five fishery officers (UNEP, 1986). In 1985, a field station of the International Institute for Submarine Research, Vaduz, Liechenstein, was established on the island of Kunfunadhoo in South Maalhosmadulu; it is hoped that this will stimulate further research in the atolls (Scheer *in litt.*, 20.11.85).

The island biota and reef flats have been relatively well studied but biological and ecological information on deeper reefs and marine life is generally poor, particularly on those atolls which have been rarely visited. The Green Turtle, Hawksbill, Leatherback and Loggerhead (*Chelonia mydas, Eretmochelys imbricata, Dermochelys coriacea* and *Caretta caretta*) have been reported to nest in the islands, the Hawksbill occurring in particularly large numbers in the past (Maniku *in litt.* to Groombridge, 6.11.86; Munch-Petersen pers. comm., 1985). Marine fish are extremely abundant and about 1000 species have been recorded from the reefs and surrounding ocean, making it one of the most species-rich marine areas in the world (Munch-Petersen, 1982 and 1985). Reef molluscs of the family Conidae are described by Kohn (1968) and Kohn and Robertson (1966) and in general by Smythe and Phillips (1971). Barthel (1981) describes the reef boring mollusc *Lithophaga obesa* in South Male. Feare (1984) describes the status of seabirds breeding in the Maldives, but does not differentiate between islands. Eleven, and possibly fourteen, species are known to nest including five species of tern *Sterna sumatrana* (nest frequently), *S. albifrons, S. anaethetus, S. dougalii* and *S. fuscata*, two species of Noddy *Anous stolidus, A. tenuirostris*, the White Tern, the Lesser Frigatebird, the White-tailed Tropicbird and Audubon's Shearwater (*Gygis alba, Fregata ariel, Phaethon lepturus* and *Puffinus lherminieri*). The terrestrial avifauna is described by Phillips (1963), Phillips and Sims (1958) and Scheer (1960a). Two fruit bats, *Pteropus ariel* and *P. hypomelanus maris*, are the only native mammals (Hill, 1958). Fosberg *et al.* (1966) and Sigee (1966) describe terrestrial and marine vegetation and Hackett (1977) and Tsuda and Newhouse (1966), marine algae. There are a few areas rich in mangroves *Rhizophora* spp. (Moutou, 1985).

**Reef Resources**

The population (173 200 in 1984) is distributed throughout the archipelago on about 200 islands, with concentrations in Male (where the capital Male is situated), in Noon-Shaviyani and in the Huvadhu/Addu group in the south (Kenchington, 1983; Moutou, 1985; Munch-Petersen pers. comm., 1985). Non-permanently inhabited islands have a floating population of about 1000, consisting of small groups of palm tenders (Munch-Petersen, 1985); smaller islands are visited for short periods for collection of firewood and coconuts (Kenchington, 1983). The main livelihoods have traditionally been fishing and agriculture.

Munch-Petersen (1985) describes the historical use of marine resources by Maldivians. The collection and export of the money cowrie *Cypraea moneta* played an important role in the settlement of the wider part of the archipelago and, with giant coconuts that drifted from the Seychelles, dried fish, tortoise-shell and black coral, formed the bulk of Maldivian exports well into this century. Shells and corals are now collected for the souvenir trade and black coral is processed for export (UNEP, 1986). Reef fish are exported for the aquarium fish trade (Wood, 1985).

Fishing is dominated by the pole-and-line methods used for pelagic species, particularly the Skip-jack Tuna *Katsuwonus pelamis*, and trolling-line fishing for other tuna-like fish such as *Neothunnus macropterus, Auxis thazard* and *Euthynnus affinis*. Tuna are consumed locally and also exported (Munch-Petersen, 1982 and 1985). Bait and hook fishing on the reefs is important on a number of atolls (Munch-Petersen pers. comm., 1985). In general, collection of reef resources for food is carried out on only a small scale and reef fish, turtles, molluscs, crustaceans (spiny lobsters) and octopus are normally only eaten when tuna is not available. However, some molluscs such as *Strombus gibberulus, Atactodea striata, Turbo argyrostomus* and *Nerita* spp. are important for food and some larger gastropods, e.g. *Cassis cornuta, Lambis* spp., and the bivalve *Athrina vexillum* are sometimes collected (Munch-Petersen, 1985). The Giant Clam *Tridacna gigas* is not eaten by islanders. Sharks and Manta Rays are caught for the liver (oil). Green Turtle eggs are collected for food but the turtle itself is not usually consumed (Munch-Petersen pers. comm., 1985).

Coral rock has traditionally been used for housing and in the construction of buildings of significance such as mosques. It is now the main building material in the archipelago, particularly in Male, Addu and the tourist resorts (Bernini, 1981; Burchett, 1982; Salm, 1975; Wood *in litt.*, 4.1.85). The massive species, *Porites lutea, Goniastrea retiformis* and *Platygyra lamellina*, are mainly used but dead coral rock of *Acropora humilis* is also used, the living part being thrown away. Coral rock is usually mined from the rim of shallow faroes, where living coral is found, mostly from inside the atolls, but more recently from outer atoll reefs. It has been estimated that a minimum of 3.3 million cu. ft (93 446 cu. m) of coral rock have been extracted over the last 13 years on Male (Brown and Dunne, 1986), much of it from around the islands of Mamagilili and Thimarafushi (UNEP, 1986).

Coral is also used decoratively in the interior design of tourist resorts and large quantities of coral jewellery are sold. In the 1970s, considerable quantities of coral were exported to India, but it is not known if this still occurs (Brown and Dunne, 1986). A limited amount of *Acropora* is burnt to make lime for chewing with betel nuts (Brown and Dunne, 1986; Munch-Petersen pers. comm., 1985).

Since the early 1970s, tourism has developed rapidly and the national income from tourism has surpassed that of fishing since the 1980s (Munch-Petersen, 1985; UNEP, 1986). Tourist resorts multiplied from two in 1972 to 56 functioning and five under construction in 1985. Uninhabited islands have been specially set aside for the industry and in numerous cases the hotel facilities are the only buildings on the island; in some instances, Maldivians have been moved off the island (Moutou, 1985; Munch-Petersen *in litt.*, 4.10.85). Most resorts are on North and South Male and more recently on Ari (five completed, five under construction) (Scheer *in litt.*, 20.11.85), which are served by the main airport on Hulule Island near the capital, Male. However, it is reported that resort building is not permitted by the Department of Tourism at present and that the next phase will take place between 1987 and 1989 when 13 resorts will be built at the southern end of Ari (Brown and Dunne, 1986).

**Disturbances and Deficiencies**

The greatest threats to the reefs come from the relatively rapid establishment and growth of the tourist industry and the introduction of mechanized fishing (Munch-Petersen pers. comm., 1985 and *in litt.*, 4.10.85). The Maldivian population has more than doubled in the last 50 years and is still increasing rapidly, placing non-pelagic marine resources under heavy pressure. Tourism and new import/export links have created new demands for a variety of natural products. The airport, built in 1966 and subsequently enlarged, helped to increase the number of visitors from 1100 in 1972 to 83 800 in 1984 (Munch-Petersen, 1985).

Many of the tourist islands are lagoonal islands, although islands on the atoll rim are also used. The natural vegetation is often cleared to make the islands "more attractive" and leaf litter is regularly removed, leaving a canopy of coconut palms over plain coral sand and a mixture of ornamental plants. On several islands the organic litter is burned and is lost to the island ecosystem. Since few birds visit such islands, there is minimal organic input from that source. Water is drawn extensively from wells and, at least after dry periods, becomes sulphurous and saline as the water lens drops, even in the centres of the islands. There is thus a break in the organic and nutrient recycling process and an alteration of the water table and which may in the long term have adverse effects on these islands. There are already fears that the tourist carrying capacity of Bandos and Kurumba (Vehamanafushi) has been reached.

Reef flats have suffered to varying degrees, especially on Male, where the town is being enlarged, mainly to the west by infilling of the reef with coral; on Hulule, the adjacent island where the airport has been constructed over the reef flat; and on some of the tourist islands of North and South Male. Runways are being built on Kaddu Island on Hadhdhunmathi and on Hanimadu (Maninaa) on South Thiladhunmathi, following which resorts will be established. The former military base on Gan (Addu) is to be transformed into a large tourist complex and the airport will be enlarged to provide landing facilities for larger planes (Scheer *in litt.*, 20.11.85).

Coral mining has caused significant damage to the reefs. A small reef north-east of Furana Fushi in Male which used to be popular with divers has now been virtually stripped (Kenchington, 1983). In some areas coral has been mined even when a request was made not to do so to prevent the area being spoilt for tourists. A recent study on the impact has been carried out (Brown and Dunne, 1986). Reef sites which have not been mined have coral cover from 11 to 60% and mixed communities dominated by *Pocillopora verrucosa* and *Acropora humilis*. At mined sites, coral cover is only about 1% and diversity is greatly reduced; in some cases living coral is totally depleted and there is generally a reduction in reef fish diversity and abundance, including important bait fish such as *Chromis* spp. Although a little regeneration has been found at some sites, recovery after 10 years was found to be minimal. The reefs may take a minimum of 50 years to recover to optimum conditions and some may not recover at all (Brown and Dunne, 1986). There is a proposal to surface 16 mi. of road on Male (all roads are currently unsurfaced) and collection of coral rock for hard core has already started. About 1 496 000 cu. ft

(42 362 cu. m) will be required if the project goes ahead, and atoll chiefs have been ordered to collect 6000 cu. ft (170 cu. m) from each inhabited island. Extrapolations suggest that North Male would be barren of all shallow reefs by the year 2014 (Brown and Dunne, 1986).

The construction of groynes, breakwaters and jetties has caused locally severe disturbance to some fringing reefs. On some of the tourist islands, walls of coral are built along the reef top and a passage is cleared out from the beach to the reef front. This provides a sandy lagoon free from coral for swimming and easy access to the reef, but may affect the reef in the long term through alteration of water circulation and sedimentation. Anchor damage and siltation caused by speed boats are becoming problems (Munch-Petersen, 1985 and pers. comm., 1985). Other potential threats include pollution from factories now being built on some islands, increased shipping traffic with the risk of oil spillages and dumping, inadequate waste disposal and the overuse of water pumps and fertilizers for agriculture (Munch-Petersen pers. comm., 1985). Domestic pollution is becoming increasingly serious (UNEP, 1986). Dredging for sand takes place but is apparently well regulated (Wood *in litt.*, 4.1.85) although dredging has resulted in siltation in some areas particularly around Hululele, during construction of the airport (UNEP, 1986).

Traditional fishing methods and a system of government monopolies (for example, the Sultan used to have a monopoly on turtle shell and black coral) helped to prevent overexploitation of marine resources in the past. However, motorized sea transport has had a major impact as the entire archipelago can now be reached (Kenchington, 1983; Munch-Petersen, 1985). Small islands are now visited, causing disturbance to bird colonies and turtle breeding grounds. Shells, black coral, spiny lobsters and other marine curios and foods are collected to satisfy the demands of the tourist industry around North Male and increasingly throughout the rest of the archipelago (Burchett, 1982; Moutou, 1985; Munch-Petersen, 1985; Salm, 1975; Wood *in litt.*, 4.1.85). Turtles, particularly Hawksbills and Greens, are collected for sale to tourists and for export as preserved specimens, particularly to Sri Lanka and Singapore (Hoffmann *in litt.*, 15.1.85; Moutou, 1985) and are now seriously threatened (Munch-Petersen, 1985). The construction of the airport promoted exports of corals and fish (Munch-Petersen, 1985). The collection of fish for the aquarium trade is well regulated (Wood, 1985) but may increase if controls are introduced by other exporting countries. Although huge quantities of money cowries were traditionally exported, only mature, thick shelled specimens were collected and there is little evidence of overexploitation. There are now no such controls but, although the trade is still large with thousands being shipped to India for jewellery, this may still not be on as large a scale as in the past (Moutou, 1985; Munch-Petersen, 1985). Spearfishing by European tourists was said to have had a noticeable impact on reef populations in the 1970s (Salm, 1975). There are some reports of fishing with explosives (UNEP, 1986).

**Legislation and Management**

A National Environment Council has recently been created under the Ministry of Home Affairs, consisting of representives from different Ministries, such as the Department of Tourism which has a particular interest in ensuring the conservation of natural resources (Munch-Petersen *in litt.*, 15.12.86; UNEP, 1986). However, it has no legislative power.

There is a minimum size for the collection of marine turtles and spiny lobsters but this is rarely enforced. Turtle shells and black coral may only be sold or exported as finished, manufactured products. The import of spearguns is forbidden; it is not clear whether spearfishing is totally forbidden, whether it may be carried out under license or whether spearfishing by non-Maldivians is just discouraged around the tourist islands (Munch-Petersen pers. comm., 1985; UNEP, 1986). The collection of marine organisms is supposedly prohibited around all tourist islands by tour operators and diving instructors who are generally interested in maintaining the health of the reefs for the tourist industry (Munch-Petersen, 1985 and *in litt.*, 4.10.85; Salm, 1975; Wood pers. comm., 1985). The Department of Tourism has reportedly decided that all future resort construction must use concrete blocks rather than corals (Brown and Dunne, 1986). Legislation has recently been promulgated defining particularly areas for mining; mining is to be forbidden around islands and may only take place on the "reefs" (UNEP, 1986). There is a quota on the number of live fish which may be exported for the aquarium fish trade and collectors must be licensed. Enforcement is probably poor for most of this legislation. All land is the property of the state, but uninhabited islands may be rented out by the government to persons of importance (Munch-Petersen, 1985). There are no marine protected areas in the archipelago.

**Recommendations**

In 1983, the government commissioned Unesco to survey the marine environment of the islands for the purpose of improving its management (Kenchington, 1983). More recently, a survey by a Danish firm has produced an additional set of recommendations (Munch-Petersen pers. comm., 1985). The National Environment Council will be sending out an expedition to survey the wildlife of the islands, particularly turtles and seabirds and there are plans for the establishment of a Wildlife and Conservation Unit in 1987 (Kirby, 1986), as recommended in the Danish survey (Munch-Petersen pers. comm., 1985). Brown and Dunne (1986) point out the need for one Government Department to be responsible for coral reefs, since at present the Ministry of Fisheries, the Department of Tourism and the Department of Public Works are all involved. They also recommend the setting up of a three year research project to formulate a management policy for reefs and to train Maldivians in reef management. Recommendations in the Danish survey included the development of environmental education programmes for local people and tourists, the drawing up of a Nature Conservation Act (a draft has now been formulated), improved enforcement of existing legislation and the ratifying of international wildlife conventions (Munch-Petersen pers. comm., 1985).

The size of the Maldivian Archipelago and its central location in the tropical Indian Ocean, isolated from continental land masses, make it a biogeographical feature of world importance which should be represented within the Biosphere Reserve system and probably also on the World Heritage List. Kenchington (1983) proposed that Ari would be a suitable site. The need for a marine park in the Maldives is emphasised in the Corbett Action Plan (Objective 3.3) (IUCN, 1985). The Danish firm recommended a system of "strict nature reserves" (open only for scientific purposes) and nature reserves (open to tourists and local people, zoned to take into consideration whether or not islands are permanently inhabited, and the requirements of local people (Munch-Petersen pers. comm., 1985). It has been suggested that such zoning schemes could be applied to Felidhu (including Wataru), Makunudu (South Thiladhunmathi), Faadhippolhu, Mulakatholhu, North and South Nilandhe, Hadhdhunmathi and Kolhmadulu. Further work is required before these areas can be designated, but the Government is reported to be developing a strategy (UNEP, 1986).

Brown and Dunne (1986) give detailed recommendations for dealing with the problem of mining coral rock. Attempts should be made to reestablish corals in heavily mined areas, possibly by building artificial reefs or transplanting corals. The use of alternative building materials, particularly coral blocks of coarse coral sand and cement, should be encouraged. The suggestion is also made that an entire inner atoll submerged reef should be used for mining, rather than the superficial layers of many reefs. A feasibility study would be required, and funding to provide the technical expertise and technology would be needed, but it has been estimated that this method could supply enough material to satisfy demand over the next 100 years.

The impact of tourism, anchor damage, ship operations and the collection and trade in shells, corals, spiny lobsters, turtles and other fauna and flora of the islands should be evaluated and controlled (Munch-Petersen pers. comm., 1985). Recommendations for improved legislation include banning exports of coral fish (although if this is satisfactorily regulated, it could be permitted (Wood, 1985)), banning spearfishing and the import of spearguns (if this has not already been done), controlling collection of molluscs (other than food species and the money cowrie) which are popular in the marine curio trade such as *Charonia tritonis, Cassis cornuta, Cypraecassis rufa* and *Lambis* spp., banning the collection, sale, resale and consumption of undersized and berried spiny lobsters, banning the collection of turtles and eggs and restricting the collection of black coral to areas with an established local tradition of exploitation and prohibiting collection within the proposed tourist zones.

Other priority issues considered by Kenchington (1983) and Munch-Petersen (pers. comm., 1985) were the development of a sewerage system for Male (which is now being planned (Munch-Petersen *in litt.*, 15.12.86)) and collection and disposal methods for wastes on the capital and hotel islands, and the creation of pollution control measures for urban and commercial development. Oil pollution controls and contingency measures must be established, in relation to those being drawn up for other countries in the Indian Ocean. The tourist carrying capacity of the islands must be studied in greater detail, greater attention should be paid to the selection of dive sites, and fixed mooring buoys should be established to prevent anchor damage.

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## ADDU

**Geographical Location** The southernmost atoll of the Maldives, and the only one south of the Equator; 0°34'-0°42'S, 73°05'-73°15'E.

**Area, Depth, Altitude** Approximately 19 x 15 km, with an exceptionally deep lagoon for its area, reaching 80 m depth. To seaward, the reef slopes descend steeply and depths of 1 or 2 km are encountered only 2 km off shore.

**Land Tenure** Government-owned.

**Physical Features** The climate of Addu differs slightly from that of many other atolls due to its southerly, more equatorial position but is similar to that of other Equatorial areas such as Foammulah and Huvadhu. From December to February, winds are mainly from the north, while in July and August the south-east trades dominate. Cyclones are very rare since the atoll lies so close to the Equator. Rainfall is between 2000 and 2500 mm a year. Currents are predominantly easterly, and are part of the Equatorial Counter Current in January and part of the Indian south-west monsoon in July, although the latter is very weakly developed (Couper, 1983). The lagoonal currents are described by Spencer Davies *et al.* (1971). The atoll has two passes in the north and two in the south-east; on a flood tide currents flow into the lagoon through one pass in the south-east and one in the north, and exit from the other two which are located very close to the former. There is no explanation for this curious pattern. On a flood tide, water is continuously pumped across the reef flat in the south part of the atoll into the lagoon; measured currents have a velocity of 0.1-1.1 m per second (Stoddart *et al.*, 1966). On ebb tides, water exits from all four channels. Tidal range is about 1 m at springs and the tidal pattern is mixed, mainly semi-diurnal. Sea temperatures are approximately 28-29°C throughout the year and there seems to be little variation with depth to at least 40 m. Air temperatures are almost identical. Salinity is in the range of 33.8-34.7 ppt.

Islands exist around much of the perimeter except in the north, and a total of 65% of the seaward reef edge is backed by land (Stoddart *et al.*, 1966). The island and reef structure of Gan, which is the most southerly island in the atoll, has been described by Stoddart *et al.* (1966) and Spencer Davies *et al.* (1971). Other islands in the atoll were visited by Scheer (1971 and 1972) who provides descriptions which enable various different parts of the atoll to be compared. The atoll was also described by Sewell (1936a).

**Reef Structure and Corals** The lagoon reef flat at Gan is 120 m wide, which is narrower than the lagoonal reef flats in the north of the atoll, and has four distinct zones: the Inner Zone, Mixed Coral Zone, *Acropora formosa* Zone and Outer Zone. The Inner Zone extends from the beach to about 35 m off shore and has no living corals. The substrate is sand, followed by rubble and coral fragments, with a few species of molluscs and echinoderms; the seagrass *Thalassia* occurs in broad swathes. The Mixed Coral Zone extends from 35 to 65 m from the beach. Coral diversity and cover increases with distance from the shore. *Acropora* species and *Heliopora* are characteristic and maximum coral cover is about 15%. The *A. formosa* Zone starts abruptly after this and extends outwards for about 20 m. *A. formosa*, with an increasing variety of other species, covers up to 70% of the substrate, faviid corals becoming increasingly important. The Outer Zone commences about 85 to 110 m from the beach. *A. formosa* is still present, but is not dominant, and other acroporids appear. Faviid corals and other pocilloporids increase in diversity and number; total coral cover is approximately 60%, with the remainder of the reef flat being covered with unconsolidated coral rubble and patches of sand. The reef flat begins to dip in this region to a depth of 2 m or more and coral growth is very vigorous and diverse, occupying up to 90% of the substrate. There is little or no calcareous red algae, and extension of the reef into the lagoon appears to result solely from growth of the loose framework of corals.

The reef slope has high coral cover to about 10 m depth and is followed by another zone of *A. formosa* which extends to about 25 m depth. Much of this coral appears to have fallen from higher parts of the reef rather than grown here, since only about 10% of it is living. Fungiids are abundant. Below 25 m large colonies of *Diploastrea heliopora* provide stable substrate and increase live coral cover to 50%; chutes formed by slips of segments of reef and corals occur and are occupied only by fungiids. Between the islands of Gan and Fedu is a sand delta which interrupts the lagoonal reef slope.

The seaward reef flat is much more extensive than the lagoonal side and extends out for 2 km. Four zones have been distinguished: Reef Flat Platform, Rubble Zone, Moat and Algal Platform. The first of these is a platform of coral rock with a sand veneer, partly covered with the seagrasses *Thalassia hemprichii* and *Cymodocea ciliata*. Coral colonies of various species form micro-atolls. The

Rubble Zone to seaward is exposed at low spring tides. The rubble is arranged into "tongues" which extend perpendicular to the edge of the reef; these appear to be the result of storm activity and there are few live corals. The Moat Zone is continually submerged and supports some corals, but is largely rubble and algae. The Algal Platform is 30-50 m wide and composed of calcareous red algae of the *Porolithon* type. Spurs, continuous with the ridge and composed of the same material, extend to seawards; they are separated by grooves of about 2 m wide with steep sides. A few species of *Acropora, Pocillopora* and *Millepora* are found, together with large amounts of a green zoantharian. In contrast to the lagoonal reef edge, the seaward reef edge is constructed principally of calcareous red algae.

The spur and groove formation extends to seaward about 100 m off Gan, and up to 300 m off other parts of the atoll. To seaward of the spurs, ridges of enhanced coral growth corresponding with the algal spurs continue for 250 m to seaward, as is common in many medium to high energy reef slopes. Massive *Acropora* species characterize the area, with *A. formosa* and *Echinopora* sp. while in the grooves or gullies loose fragments covered by red algae are abundant. From 20 m depth, alcyonarians increase in abundance and scleractinian corals show a diminished cover. At 45 m depth the substrate flattens and is composed largely of gravel and sand.

Reefs in other parts of the atoll are similar. Off Midu, the lagoonal reef edge zone is indistinct and the reef flat merges gradually with the lagoonal reef slope which is less steep than that at Gan. On the seaward side of Midu, the reef edge is indistinct and, at about 3 m depth, luxuriant coral gives way to a barren area of broken coral fragments. From 7 m depth, where the slope increases, abundant coral growth is found again and there is a drop-off at 25 m.

Addu has few lagoonal knolls or coral patches and only three reach the surface, two of which apparently support luxuriant coral growth. Five-fathom Shoal reaches to within 9 m of the surface and has an upper surface of loose coral fragments, minimal live coral, and an abundance of leafy algae. The north-west slope of this knoll has a substrate of firm sand to 24 m depth, with a few corals. Several other knolls and a so-called mini-atoll in the north-west part of the lagoon examined by Scheer (1971 and 1972) also have little coral on the reef slopes, although dense bands are found in some places such as gently sloping ledges.

Off Hitaddu, the lagoonal reef flat is 1300 m wide and the zonation is similar to Gan although extended. There are extensive sandy patches with seagrass and increasing cover by corals at the lagoonward side. The reef slope descends abruptly to the lagoon floor at 30 m. The seaward slope is only 200 m wide, fronted by a low algal ridge and a shallow spur and groove system which drops to about 8 m, followed by a zone with scattered corals to 18 m. A more gentle slope with *Halimeda* leads to an almost flat terrace at 40-50 m. Only nine coral genera were found on the seaward reef in this area. The seaward slope at the northern rim between Hitaddu and Kudu Kanda channel descends steeply and is covered with *Acropora* at first, then with plate-shaped corals such as *Echinopora, Montipora, Pachyseris, Echinophyllia* and *Mycedium*, and has hollows filled with *Dendrophyllia*.

Xarifa Reef in the northern part of the lagoon near Hitaddu was examined by Scheer (1971 and 1972) in some detail. It is a hooked extension of the northern reef flat, produced by the inward flowing flood stream through the Kudu Kanda channel and is connected to the reef flat by a ridge with 100% coral cover, predominantly *Acropora, Stylophora* and *Pocillopora*. The eastern and central parts are covered by rubble with calcareous red algae. In the west, the rubble is piled up to form an emergent cay. The reef slopes on all sides descend to the lagoon floor at an angle of about 45°, and support a high diversity of coral cover ranging from 10% to 90%.

About 55 hermatypic genera have been recorded from Addu (Pillai and Scheer, 1976; Wells and Davies, 1966).

**Noteworthy Fauna and Flora** The Maldivian Pond Heron (*Ardeola grayii phillipsi*) is common and is an endemic subspecies of the Indian Pond Heron (Scheer, 1960a). Addu is the only breeding site of the White Tern *Gygis alba* in the Maldives. The fruit bat *Pteropus hypomelanus maris* is the only native mammal on the atoll (Hill, 1958) and has been seen only once (Moutou, 1985a and b). Predatory gastropods around Gan are described by Taylor (1978).

**Scientific Importance and Research** More research has been carried out on Addu particularly on Gan and on the reefs between Hitaddu and the Kudu Kanda channel, than elsewhere in the Maldives. The 1964 expedition to study the reefs is described by Stoddart (1966a).

**Economic Value and Social Benefits** Gan was a British military air base from 1942 to 1976. The British buildings are now used by a Hong Kong factory for clothes which has established two sewing mills. In 1977, the atoll had a population of 14 100. A tourist resort was established at Gan and small planes run twice a week from Male (Scheer *in litt.*, 20.11.85).

**Disturbance or Deficiencies** Causeways built on Gan may have affected the reef (Kenchington, 1983). The military base is to be transformed into a large tourist complex and the airport is to be enlarged to provide landing facilities for large planes (Scheer *in litt.*, 20.11.85).

**Legal Protection** None.

**Management** None.

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## ARI

**Geographical Location** Central Maldives on western part of the double chain of atolls within the district of Ari; 4°17'-3°30'N, 72°41'-72°58'E.

**Area, Depth, Altitude** About 32 x 87 km; greatest depth nearly 80 m.

**Land Tenure** Government-owned.

**Physical Features** The atoll is oval-shaped with low islands rising not more than a few metres above sea-level. Reefs to seaward appear to extend to beyond the depths of hermatypic corals. Inside the lagoon, reef slopes extend to at least 45 m, although the lower parts become increasingly sand covered. Ari is notable for its ring-shaped reefs, or faroes, which form the perimeter of the atoll in place of the more usual continuous, linear reef flat; the faroes often support islands.

**Reef Structure and Corals** Two faroes, one mini-atoll and one patch reef have been surveyed. One, west of the tourist island of Fesdhu, is 1240 x 640 m with a lagoon (or "velu") about 10 m deep, and a rim which is submerged between 0.4 and 1.1 m and is unbroken by channels. The oval faro is itself divided into two by a ridge crossing the lagoon at the same depth as the rim. The reef flat is 40-70 m wide and composed of coral fragments (50%), sand (30%), *Acropora* (12%), and live coral of other species attached to the small amount of hard substrate. Coral growth decreases towards the seaward edge of the reef and increases towards the lagoon edge where reef flat corals become luxuriant. In the lagoon itself corals are very sparse, consisting only of a thin branched *Acropora* species. Substrate composition on the dividing partition in the faro is broadly similar to that on the rim. The outer edges of the faro slope steeply to 20 or 25 m depth and then more gradually to 45 m. The faro appeared to have died some years ago. In 1958, the slopes were covered by dead corals and coral rubble, with many colonies still in their original growth position, but covered with calcareous algae and overgrown with *Halimeda*. Living corals had settled again between the dead corals and coral rubble. On the south and west sides, consisting mainly of coral debris, Alcyonaria provided dense cover to 25 m (Scheer, 1971 and 1972).

A second faro north-east of Fesdhu was examined by Scheer (1971) and has a diameter of 1.5 km, a lagoon 14 m deep with a diameter of 800 m and a rim submerged to 1.5 m. Slopes with gradients from 35° to 45° had broken corals, dead *Acropora*, sand and only 15% live coral, mostly *Porites* and *Millepora*. The reef flat, about 350 m wide, is covered with about 50% live corals, mostly *Millepora* joined by *Pocillopora, Goniastrea, Porites, Acropora* and other species. It seems that the slope on the southern side of the faro has broken off, showing, in 1958, a nearly vertical wall with grottos to 20 m depth. The gradient then decreases more and more to the lagoon floor at 45 m depth. Slope and grottos had a high diversity of corals.

North of this circular faro, there is a mini-atoll of 400 x 200 m with slopes descending at 45° (Scheer, 1971). The rim of the reef flat is covered with about 80% live coral, mostly *Acropora*. The reef flat itself has dead corals with coral fragments partly cemented together by calcareous algae interspersed with live corals. This structure was termed a mini-atoll by Scheer (1971 and 1972) and belongs to a row of similar formations which differ from each other by an order of magnitude (micro-atoll 1 m, patch reef 10 m, mini-atoll 100 m, faro 1000 m, atoll 10 000 m). Between the circular faro and the mini-atoll there is a patch reef with a diameter of 150 m and a depth at its surface of 3 m. Coral growth is irregularly distributed and is mostly *Acropora* and *Millepora*.

24 hermatypic coral genera have been collected from Ari and are described by Pillai and Scheer (1976).

**Noteworthy Fauna and Flora** Green Turtles *Chelonia mydas* nest in the atoll (Maniku *in litt.* to Groombridge, 6.11.86).

**Scientific Importance and Research** Scientific work on the reefs is limited to that of Scheer (1971 and 1972), who visited the atoll on the Hans Hass "Xarifa" expedition, and Pillai and Scheer (1976).

**Economic Value and Social Benefits** In 1977 the atoll had a population of 6300. Plans are in hand for future expansion of the tourist industry (Kenchington, 1983). Five tourist resorts (Bathala, Fesdu, Halaveli, Kudafolhudu and Mayafushi) are already working and five more (Dhidoofinolhu, Ellaidu, Gangehi, Madoogali and Velidu) are under construction (Scheer *in litt.*, 20.11.85). Between 1987 and 1989, 13 resorts are to be built in the southern part of the atoll (Brown and Dunne, 1986).

**Disturbance or Deficiencies** The reason for the high proportion of dead coral cover on the slopes and reef flats of the faroes is not known (Scheer, 1971 and 1972). Such mortalities were not observed on other atolls and may therefore be due to a localized disturbance.

**Legal Protection** None.

**Management** None.

**Recommendations** Kenchington (1983) recommended that planning for controlled and sustained use of Ari is urgently required and suggested that it should be designated as a Biosphere Reserve. Research would need to be carried out to provide basic data for management.

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## FAADHIPPOLHU

**Geographical Location** On the eastern arm of the double chain of atolls; 5°34'-5°14'N, 73°19'-73°38'E.

**Area, Depth, Altitude** Approximately 35 km in diameter, with a maximum lagoonal depth of about 59 m.

**Land Tenure** Government owned.

**Physical Features** Gardiner (1903) described the atoll and its islands.

**Reef Structure and Corals** Scheer (1971) described a reef flat about 300 m wide on the west side of the atoll. From the island to the lagoon, a sandy zone preceeds an area of seagrass, followed by an increasing abundance of corals. Near the edge of the reef flat, live corals covered 60% of the substrate, with an additional 10% cover provided by alcyonarians. On the lagoonal reef slope at 2.5 to 5 m, coral cover reached 90% with *Acropora, Porites, Pavona, Montipora* and *Leptoria*. A total of 23 hermatypic coral genera were recorded (Pillai and Scheer, 1976).

**Noteworthy Fauna and Flora** Turtles probably nest on the atoll (Maniku *in litt.* to Groombridge, 6.11.86), but detailed information was not available at the time of going to press.

**Scientific Importance and Research** Besides the description of Gardiner (1903), none apart from the work of Scheer (1971) and Pillai and Scheer (1976).

**Economic Value and Social Benefits** Not known.

**Disturbance or Deficiencies** Not known.

**Legal Protection** None.

**Management** None.

**Recommendations** The north-east reef area, including the island chain from Guraidhoo to Maidhoo and Bodu Huraa, has been recommended as a strict nature reserve. A broad central area, including a number of northern and eastern islands, and the southern island of Aligaa, has been recommended as a nature reserve (Munch-Petersen pers. comm., 1985).

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## NORTH AND SOUTH HUVADHU

**Geographical Location** Southern Maldives; 0°55'-0°12'N, 72°56'-73°31'E.

**Area, Depth, Altitude** 43 x 35 miles (69 x 56 km). The lagoon is 90 m deep in the centre.

**Land Tenure** Government-owned.

**Physical Features** The largest non-compound atoll in the Maldives (Gardiner, 1903). The rim totals 130 miles (209 km) and is cut by about 40 passages, some of which have depths of 60-80 m, almost the average depth of the lagoon. Much of the rim is awash, or nearly so, at low water. Islands are most common on the east, south and south-west sides and on a cluster of knolls in the north-west of the lagoon.

**Reef Structure and Corals** Parts of the reef rim, especially in the south-west, are double with depressions in their centre reaching several metres deep many of which communicate with the lagoon. They are not described as faroes because of their linear nature, although they appear to have a similar cross section viewed across their shortest dimensions. Many sections of the rim are crescent-shaped, with extended "horns" curving into the lagoon in the manner of a partly developed faro. The lagoon is very open and has about 70 knolls, a much lower density than on most Maldivian Atolls. The land on many of them is, in Gardiner's (1903) view, being washed away. They have steep sides to 40 or 50 m, composed of hard substrate or rubble, followed by a substrate of fine sand and mud.

Gardiner (1904 and 1905) and Pillai and Scheer (1976) described the corals. A total of 16 hermatypic genera are known.

**Noteworthy Fauna and Flora** Turtles probably nest in the atoll (Maniku *in litt.* to Groombridge, 6.11.86) but detailed information was not available at the time of going to press.

**Economic Value and Social Benefits** The atoll had 12 700 inhabitants in 1977. Two islands are used for wet-land cultivation by adjacent island populations.

**Disturbance or Deficiencies** Not known.

**Legal Protection** None.

**Management** None.

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## NORTH AND SOUTH MAALHOSMADULU

**Geographical Location** North Maldives; 5°59'-5°20'N, 72°45'-73°02'E.

**Area, Depth, Altitude** Maalhosmadulu is divided into three banks (Gardiner, 1903), each of which has a series of circumscribing reefs, the areas of which, from north to south, are 320, 35 and 270 sq. mi. (829, 91 and 700 sq. km). The lagoon depths are 59, 48 and 70 m respectively. To seaward the reef drops sharply to over 200 m.

**Land Tenure** Government-owned.

**Physical Features** Gardiner (1903) favoured the view that the three closely adjacent banks were not formed individually but became separated at a later stage of growth. At present the physical character of all three banks is very similar. The rim of the atoll is not continuous, but is composed of numerous faroes, separated by depths of up to 50 m, the depth of the lagoon around the periphery. There is land on all of the reefs in the east and on a few in the west, though no part is more than 6 m above the reef flat at low water level. Some islands, however, may support sand dunes up to 10 m high for transient periods. Several islands are described by Gardiner (1903).

**Reef Structure and Corals** Reef flats around the islands range in width from fairly narrow to several hundred metres, extending from the land out to well defined reef edges. The larger reef flats often enclose pools or "velu" of varying depths, commonly 8-14 m. The lagoon has a high density of knolls, many of which reach the surface and several of which support islands. Gardiner (1904 and 1905) mentioned only two coral genera from North Maalhosmadulu, but 51 hermatypic coral species in 31 genera are known from this atoll (Scheer pers. comm., 20.11.85). A hydrozoan coral, the Red Filigree *Distichopora nitida*, known only from the Pacific, was found near the island of Kunfunadhoo at the southern rim of South Maalhosmadulu and at few other places (Scheer and Obrist, 1986).

**Noteworthy Fauna and Flora** Green Turtles *Chelonia mydas* nest in the atoll (Maniku *in litt.* to Groombridge, 6.11.86).

**Scientific Importance and Research** In 1985, a field station for the International Institute for Submarine

Research, Vaduz (Liechtenstein) was founded on Kunfunadhoo in South Maalhosmadulu.

**Economic Value and Social Benefits** In 1977 the population of North Maalhosmadulu was 7900. South Maalhosmadulu had 5200 inhabitants in its southern part and only 250 in the small northern part with one inhabited island; a tourist resort was opened on Kunfunadhoo in 1983.

**Disturbance or Deficiencies** Not known.

**Legal Protection** None.

**Management** None.

**Recommendations** Not known.

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## NORTH MALE

**Geographical Location** Central Maldives; 4°42'-4°10'N, 73°21'-73°43'E.

**Area, Depth, Altitude** Approximately 58 x 41 km, with a maximum lagoonal depth of 72 m.

**Land Tenure** Government-owned.

**Physical Features** The atoll is oval-shaped and has about 18 islands in the lagoon around which there may be strong localized currents.

**Reef Structure and Corals** Data are available on two fairly similar lagoonal islands, Bandos (Holliday, 1982) and Baros (Sheppard, pers. obs.). Both islands are conical structures rising from a sandy substrate at 40 m or greater and are typical lagoonal knolls except that their tops are emergent and capped with vegetation. The sides of the knolls have patchy coral, with 40-80% live cover interspersed with sand patches. Coral diversity is high, and dominated by tabular *Acropora* spp. and thickets of *Acropora cf formosa* on sandy expanses. Soft corals cover 10-20% of the slopes. The reef flats have large expanses of sand, with increasing coral cover towards the reef edge. Work has also been carried out on the reefs around Rasfaree, Hithi Knoll and Tulusdu (Matteuci and Russo, 1980).

**Noteworthy Fauna and Flora** No information.

**Scientific Importance and Research** On Gaha Faro just north of North Male the first feeding experiments on sharks to test protection methods were carried out (Eibl-Eibesfeldt and Hass, 1959). Brown and Dunne (1986) have studied the impact of coral mining.

**Economic Value and Social Benefits** North Male is the main commercial and tourist centre for the Maldives. The capital Male lies on the southern rim, adjacent to the new international airport on Hulule. Its population increased from 6100 in 1920, to 13 600 in 1970, 29 500 in 1977 and an estimated 38 000 in mid 1984. There are four other inhabited islands which had a total population of 1600 in 1977. In 1972, the first two tourist resorts (Bandos and Kurumba) for the Maldives were established on this atoll. There are now 28 tourist islands and in 1984 there were more than 45 000 visitors, many of whom were SCUBA divers. Reef-related tourism is therefore an important source of revenue (Kenchington, 1983).

**Disturbance or Deficiencies** In the early 1970s *Acanthaster planci* was common around Male, Kurumba, Vilingili and Bandos (Salm, 1975) but it is not known to what extent it caused damage.

The main disturbances to the reefs arise from limestone quarrying, sewage discharge, and the construction of jetties which affects the reef flats (Kenchington, 1983). For example, on Baros a wall has been built along the reef top and living coral blocks from the adjacent reef were used in its construction (Wood, 1984). High levels of algal cover and dead corals in the vicinity of the harbour on Male island are attributed to pollution. Similar symptoms of pollution were seen at Valassaru, Vilingilli and Meerufunfushi. Reclamation on Male has had a severe impact on the reef and on a number of reefs nearby (Kenchington, 1983). Waters around Bandos were notable for their lack of pollution (Holliday, 1982), although there was possibly some damage from divers as the area near the dive hut landing stage is used as a check out dive area. Substantial rubbish was found on Baros (Wood *in litt.*, 4.1.85). Over-collection of shells was reported around Male in the 1970s (Salm, 1975).

Coral mining for construction has had a devastating effect. It has been estimated that about 0.5 million cu. ft (0.014 million cu. m) of coral aggregate are required a year. Road building alone will require 1 496 000 cu. ft (42 362 cu. m) over the period 1986 to 1987. During this period, 16 mi. (28 km) of road are to be surfaced with 344 000 cu. ft (9741 cu. m) of coral rock from North and South Male. It is estimated that supplies from inner atoll faroes will be exhausted within 30 years and from the entire atoll chain within a matter of decades. Live coral is now collected from the outer atoll faroes which normally protect the islands against the monsoonal storms. Mining of coral rock has, in places, altered the microclimate and substrate, and strong currents now move across the substrate which is composed of highly mobile broken coral. Coral settlement has therefore been badly affected (Brown and Dunne, 1986). Further details are given in the introduction.

**Legal Protection** None.

**Management** Spearfishing by non-Maldivians is prohibited by the proprietors on all tourist islands (Munch-Petersen *in litt.*, 4.10.85).

**Recommendations** Kenchington (1983) recommends that alternatives to coral rock be used for building, that sewage and refuse collection be improved and that development be subject to guidelines. Brown and Dunne (1986) provide detailed recommendations for solving the problem of mining coral rock (*see Introduction*).

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## RASDU

**Geographical Location** Just north of Ari on the western arm of the double Maldive chain within the district of Ari; 4°20'-4°15'N, 73°55'-73°01'E.

**Area, Depth, Altitude** Atoll less than 10 km diameter; lagoon nearly 40 m deep; outer slopes descend steeply to 45 m, where, at some places, a terrace 30 m wide interrupts the descent.

**Land Tenure** Government-owned.

**Physical Features** There are three islands (one is inhabited) in the south, and in the east, one, Weligandu, whose reefs have been studied by Scheer (1971, 1972, 1974 and 1978).

**Reef Structure and Corals** On Weligandu the reef flat on the lagoonal side had a high diversity of corals, particularly *Acropora humilis, Acropora* spp., *Porites, Echinopora, Pocillopora, Goniastrea,* and other faviids and mussids. On the outer reef flat east of Weligandu the coral composition was different, with *Acropora formosa, A. surculosa, A. humilis, A. palifera, A. irregularis, Pocillopora molokensis, P. eydouxi, Porites solida* and *Synaraea convexa* predominant. The outer reef dropped very steeply and was only interrupted between 40 and 50 m by a 30 m wide terrace. At 35 m the lagoon floor was 85% covered by sand, and had a diverse coral assemblage of typical deeper water agariciids and fungiids, particularly *Halomitra*, and other foliaceous and faviid corals. A notable feature was *Goniopora* which was reproducing by means of polyp balls (Scheer, 1960b). A total of 42 hermatypic coral genera have been recorded.

**Noteworthy Fauna and Flora** Turtles may nest on Rasdu (Maniku *in litt.* to Groombridge, 6.11.86) but details were not available at the time of going to press.

**Scientific Importance and Research** Research has been carried out by Scheer (1971, 1972, 1974 and 1978) and Pillai and Scheer (1976).

**Economic Value and Social Benefits** The population was 400 in 1977. Since then, Kuramathi has become a tourist resort (Scheer *in litt.*, 20.11.85) and Weligandu is being developed as a tourist island (Wood *in litt.*, 4.1.85).

**Disturbance or Deficiencies** Coral is being taken from the reef at Weligandu for construction purposes (Wood *in litt.*, 4.1.85). A breeding site for the rare Crab Plover *Dromas ardeola* on Weligandu has been eliminated (Scheer pers. comm., 1985).

**Legal Protection** None.

**Management** None.

**Recommendations** Not known.

# MAURITIUS

## INTRODUCTION

### General Description

Mauritius is the central member of the Mascarene group of islands and is located at 20°S, 58°E. It has a mountainous topography contained within a coastline of only 200 km, and a total area, including several much smaller adjacent islands, of 1865 sq. km. Rodrigues, to the east, and the Cargados Carajos Shoals (St Brandon Islets) and Agalega, to the north, also come under Mauritian jurisdiction. Mauritius is subject to the south-east trades, and as a consequence its coast is predominantly affected by swell from the south-east (Couper, 1983). Cyclonic depressions occur almost annually, and the severe sea states induced by some of these affect the reefs. Tides are only 0.6 m at springs, and surface temperature varies seasonally between 22 and 27°C.

Scientific publications on the reefs include Faure (1975, 1976 and 1977), Faure and Montaggioni (1971), Montaggioni and Faure (1980), Pichon (1967 and 1971) and Salm (1976). Montaggioni (1974 and 1976) and Pichon (1971) describe the geological history of the reefs, which tend to have an interesting geological basis with basalt tending to outcrop a few metres deep on reef slopes. Michel (1974) provides a summary of publications on general marine aspects of the area.

There are 150 km (300 sq. km in area) of fringing reef around the island (UNEP, 1984) which is cut by surge channels and river mouths, but is otherwise only absent from two areas: a 15.5 km stretch on the south coast and two parts totalling 10.5 km on the west coast (Faure, 1975; Montaggioni and Faure, 1980). Separate accounts are given for the reefs around Baie d'Arsenal and Black River on the west coast, Port Louis on the north, Ile Plate and Ilot Gabriel off Cap Malheureux in the north, Rivière du Rampart in the north-east, Flacq and Trou d'Eau Douce in the east and Mahebourg and Blue Bay in the south-east.

At least 36 genera of hermatypic corals have been recorded from Mauritius (Pichon, 1971). Salm (1976) describes three main types of reef: peripheral fringing reefs, sheltered fringing reefs and lagoonal coral patches. There is a narrow reef flat usually less than 25 m wide. The lagoon between the shore and peripheral fringing reefs may be several hundred metres or, off the eastern shore, a few kilometres wide. It is usually only 1-3 m deep, but reaches depths of up to 6 m in the north. Sheltered fringing reefs border such channels as exist within the peripheral fringing reefs or protected bays and are characterized by a dense cover of large fragile colonies of tabular *Acropora* and foliaceous *Montipora*. The third type is patch reefs, found within the lagoon, which are rich in live corals and have a high cover of *Acropora* and *Pavona*. In addition, Faure (1977) describes a barrier reef at Mahebourg (*see separate account for* the adjacent fishing reserve) which is 400-600 m wide and 9 km long, 3-5 km off shore, and shelters a lagoon 15-30 m deep.

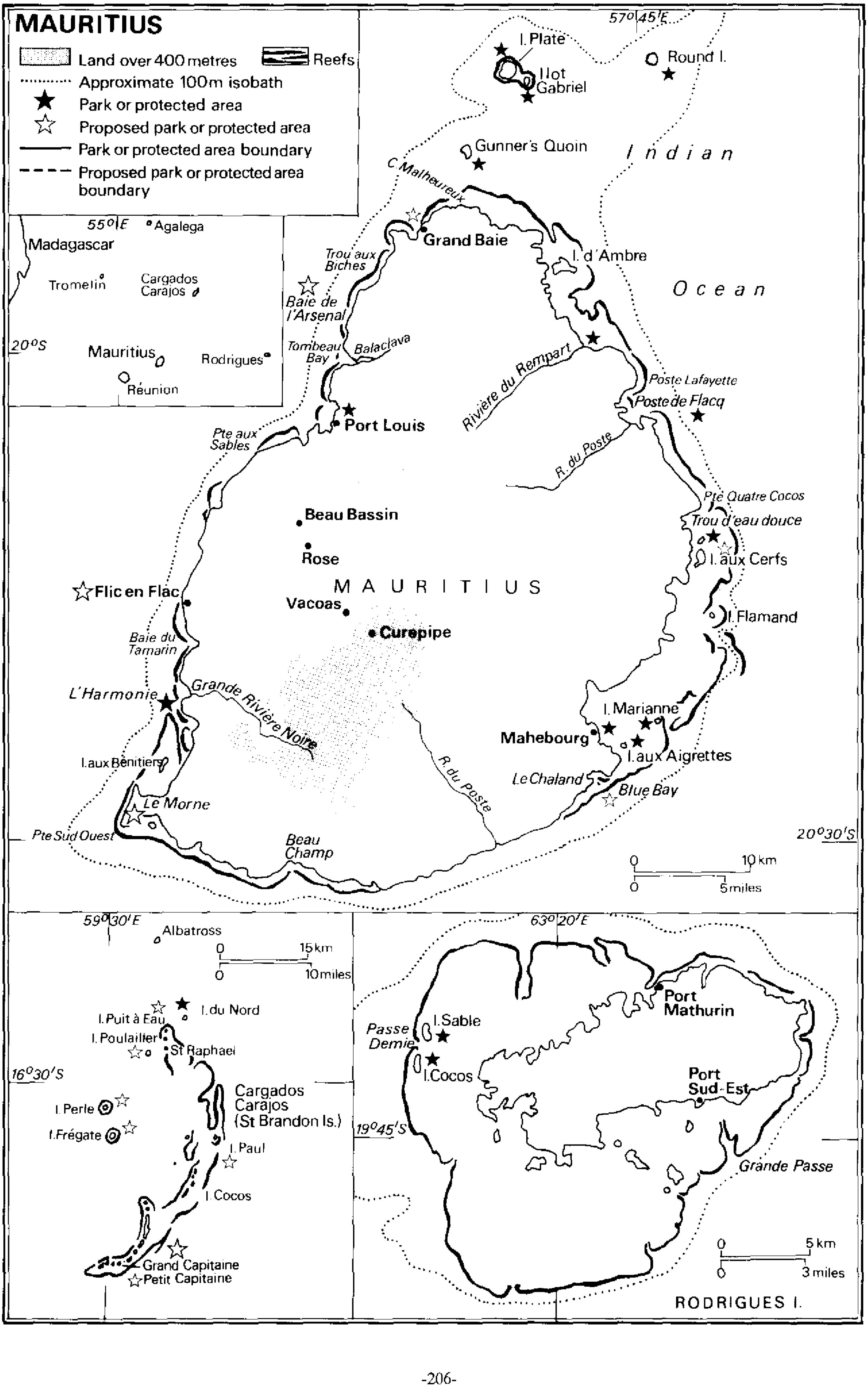
The reefs of Rodrigues and Cargados Carajos Shoals are described in separate accounts. Agalega (10°19'-10°28'S, 56°34'-56°41'E), lying 990 km to the north of Mauritius, is within its EEZ and consists of North and South Island (both sandy cays with coconuts) surrounded by some 100 sq. km of reef. The fringing reef encloses a very narrow lagoon (25-100 m wide) with no natural passes. At the landing site on North Island, the reef comes within a few metres of shore and a pass has been blasted out (Cheke and Lawley, 1983; UNEP, 1984).

Detailed descriptions of reef-associated fauna are given in UNEP (1984). Mauritius is famous with conchologists for its rich molluscan fauna, which includes a number of endemic species such as the Imperial Harp Shell *Harpa costata* and the cowry *Cypraea mauritiana* (Ceyrolle and Chakowa, in press; Henon, 1976; Michel, 1985). A total of 263 species of fish have been described (Condé and Jauffret, 1978; Monod, 1976) but Fagoonee (*in litt.*, 6.1.86) reports that some 600 species have been recorded. Several species are endemic and considered to be rare. The fish faunas at Anse de Balaclava and Trou aux Biches on the north-west coast are described by Harmelin-Vivien (1976). Atchia (1984) provides a popular account of Mauritian fishes.

Sea turtles no longer nest on Mauritius, nor in significant numbers on Rodrigues, but the Cargados Carajos have a large and heavily exploited Green Turtle *Chelonia mydas* population (Hughes, 1981). The Hawksbill *Eretmochelys imbricata* was once common but is now rare and the Leatherback *Dermochelys coriacea* is seldom seen. The Dugong *Dugong dugon* and the Coconut Crab *Birgus latro* are now extinct in Mauritius. Feare (1984) lists thirteen species of seabirds known to breed in the Mascarene Islands, including the White-tailed Tropicbird *Phaeton lepturus lepturus*, Red-tailed Tropicbird *P. rubicauda rubicauda*, and others mentioned in the following accounts. Mangroves *Rhizophora mucronata* and *Bruguiera gymnorhiza* are found on the east, south-east and north-east coasts (*see accounts for* "Fishing Reserves") and are relatively abundant in the region of Ile d'Ambre and Ile aux Cerfs (UNEP, 1984). Marine algae are described by Mshigeni (1985).

### Reef Resources

There are about 2500 artisanal fishermen on the main island, and some 2000 tons of fish are landed from the lagoon. The range of gear commonly used includes basket traps, nets, lines and harpoons, worked from small wooden boats, fewer than half of which are motorized (Fagoonee *in litt.*, 1.1.86). Since 1977, the Fishery Division has been collecting statistics on catch and effort in the lagoon, with a view to improving management as necessary (UNEP, 1984). The Mauritius Underwater Group, with the collaboration of other societies and the Ministry of Agriculture, has initiated an artificial reef project (Fagoonee, 1985b). The Mauritian fish fauna is of considerable interest to aquariologists and large numbers of reef fish are exported, mainly collected by professional divers. Dried seahorses (Syngnathidae) and



MAURITIUS
Land over 400 metres
Reefs
Approximate 100m isobath
Park or protected area
Proposed park or protected area
Park or protected area boundary
Proposed park or protected area boundary
55°E
Agalega
Madagascar
Tromelin
Cargados Carajos
20°S
Mauritius
Rodrigues
Réunion
57°45'E
I. Plate
Ilot Gabriel
Round I.
Gunner's Quoin
Indian Ocean
C. Malheureux
Grand Baie
I. d'Ambre
Trou aux Biches
Baie de l'Arsenal
Tombeau Bay
Balaclava
Rivière du Rempart
Poste Lafayette
Poste de Flacq
Port Louis
Pte aux Sables
R. du Poste
Pte Quatre Cocos
Trou d'eau douce
I. aux Cerfs
Beau Bassin
Rose
MAURITIUS
Flic en Flac
Vacoas
Curepipe
I. Flamand
Baie du Tamarin
L'Harmonie
Grande Rivière Noire
I. Marianne
Mahebourg
I. aux Aigrettes
I. aux Bénitiers
Le Chaland
Blue Bay
R. du Poste
Le Morne
Pte Sud Ouest
Beau Champ
20°30'S
0 10 km
0 5 miles
59°30'E
Albatross
0 15 km
0 10 miles
I. Puit à Eau
I. du Nord
I. Poulailler
St Raphael
16°30'S
Cargados Carajos (St Brandon Is.)
I. Perle
I. Frégate
I. Paul
I. Cocos
Grand Capitaine
Petit Capitaine
63°20'E
Port Mathurin
Passe Demie
I. Sable
I. Cocos
Port Sud-Est
19°45'S
Grande Passe
0 5 km
0 3 miles
RODRIGUES I.

pufferfish (Canthigastrinae) are sold as souvenirs. The potential for commercial harvest of marine algae is described in Mshigeni (1985).

The tourist industry is becoming increasingly important and there were approximately 180 000 visitors in 1980. Tourist pressure is greatest in the north-west of the island, with subsidiary centres in the east at Trou d'Eau Douce and Blue Bay, and in the south-west at Le Morne, with minor developments in the Black River Tamarin/Flic en Flac and Tombeau Bay areas (Robertson, 1974). There are a number of diving and snorkelling centres and a diving school at Flic en Flac. A guide to the reefs for SCUBA divers is provided by Harmelin-Vivien and Petron (1981). Popular dive sites include Large du Morne (in the south-west), Whale Rock (reached from Trou aux Biches or le Merville) which has extremely good visibility and deep canyons, the Cathedral (near Flic en Flac), Ile Plate, and Coin de Mire (Gunners Quoin). Round Island is a well-known site with a submerged crater at 25 m depth, and Roche Zozo is a spectacular underwater rock, rising from 45 m to 14 m depth. The wreck of the St Géran on the reef off Ile d'Ambre on the north-east coast is also popular. The Mauritius Underwater Group is active in the promotion of the sport (Webb, undated).

**Disturbances and Deficiencies**

Occasional cyclones have damaged the reefs, including one in 1960 which affected the sheltered fringing reefs at l'Harmonie, between Grande Rivière Noire and Petite Rivière Noire on the west coast (Salm, 1976); reefs on the east and south are also subject to cyclones (Robertson, 1974). In the early 1970s there was an explosive increase in the populations of the urchins *Tripneustes gratilla* and *Echinometra mathaei* on parts of the east coast which resulted in destruction of seagrass beds and reef areas, and the silting up of once productive lagoons. Overfishing of urchin predators such as octopus was suggested as a causal factor but there has been no research to confirm this (Procter and Salm, 1974). The Crown-of-thorns Starfish *Acanthaster planci* was present in the early 1970s but there are no definite reports of any major damage as a result of its presence (Procter and Salm, 1974; Robertson, 1974) although Fagoonee (1985a and b) suggests that it has caused problems, having increased 13-fold in nine years. At Trou aux Biches, densities increased from 30 per 10 000 sq. m in 1971 to 416 per 10 000 sq. m in 1980 (Fagoonee *in litt.*, 1.1.86).

Over the past 200 years natural forest has been reduced to less than 1% of its original cover, with much of the island given over to sugar cultivation and, in higher areas, tea (Curry-Lindahl, 1971; IUCN/UNEP, 1982; Scott, 1973; Temple, 1974; Temple *et al.*, 1974; UNEP, 1982; UN/Unesco/UNEP, 1982). There has been localized sedimentation on the south-east coast as a result of erosion (Robertson, 1974). The Round Island reefs, although not well developed, showed many signs of damage in the 1970s, possibly due to siltation (Procter and Salm, 1974). Pollution from various sources is becoming a problem (Jehangeer,1978). Pesticide run-off from agricultural land may also affect the reefs (Fagoonee, 1985a). Suspended solids from sewage outfalls on part of the west coast have resulted in extensive siltation and death of coral communities (UNEP, 1984). Near the capital Port Louis, the only major port, eutrophication is choking some of the nearby reefs (Osore, 1983).

Coral and coral sand have been taken for building, an estimated 200 000 tons being taken annually, 47% of which comes from the lagoon (Walker, 1962). Lime kilns on the east coast use live corals, especially at Bel Air, Haute Rive, Beau Champ and Mahebourg, and in 1982, an estimated 2000-3000 tonnes were taken (Fagoonee, 1985a; UNEP, 1984). The Riambel Sea Power Project on the south coast, involves the construction of a 5 km long wall, 2.5 m above the reef, to enclose a reservoir which would provide electric power and a fish farm. This could cause major damage to the reefs, but will be subject to an environmental impact assessment (Anon., 1985; Manrakhan, 1983).

Residential development along the coastline is relatively minor due to the dominance of inland agriculture, but the extensive sandy beaches and the reefs which often shelter them are being used increasingly by a vigorous tourist industry (UN/Unesco/UNEP, 1982). Reefs on the west of the island are considered to be the most vulnerable to tourist activities as they are the most accessible; those on the east and south are subject to heavy seas for much of the time. Hotel developments at Le Morne, Le Chaland and parts of Trou d'Eau Douce indirectly exert some control as the beaches are closed to the general public but the area north of Trou aux Biches is subject to intensive use. There is a large trade in corals and shells for tourists which is particularly evident around Trou aux Biches (Profitt, 1983). Many marine curios are imported but large quantities of shells are taken from the local reefs, often from areas beyond the nearshore reefs by SCUBA divers and fishermen. Anecdotal reports suggest that some of the rarer, endemic species may be becoming harder to find. Shell collecting by visitors is intensive around the hotel areas. *Tridacna maxima* is collected for food and *Pinctada* sp. may be collected for export; it is not known if either of these molluscs is overexploited. Black coral may be collected in small quantities; it is known to be abundant on the outer slope of the reef at Flic en Flac below a depth of 30 m (UNEP, 1984).

Overfishing is becoming a problem throughout much of the island. There has been a 50% decline in fish catch from reef areas in 30 years despite a six fold increase in fishing effort, the lagoon fisheries having been particularly affected (Fagoonee, 1985a; Procter and Salm, 1974; Robertson, 1974). Catch figures declined from 2500 mt in 1976 to 1375 mt in 1984 (Fagoonee *in litt.*, 1.1.86). Use of dynamite and small mesh seine nets in the lagoon, coupled with inefficient policing (30 seine nets may be used in the lagoon), have contributed to the deterioration of the reefs as well as to the loss of fish for consumption. Dynamite fishing used to occur at night and damage was reported to be visible in the Grande Baie area (Fagoonee, 1985a; Profitt, 1983), but this has virtually stopped now (Fagoonee *in litt.*, 1.1.86). Ciguatera is prevalent. There is no information on the impact of the aquarium fish trade. There may be a certain amount of anchor damage from artisanal fishing boats (Fagoonee, 1985a) and around some of the more frequently visited island reserves such as Round Island and Coin de Mire.

**Legislation and Management**

The Fisheries Act (1980), with the Fisheries Regulations of 1983, prohibits the take of undersized or berried spiny lobsters; the use of poisons and explosives; the import or export without a permit of live fish, and corals and shells, whether dead or alive; the collection of turtles and marine mammals; and specifies licence quotas for particular areas. There is a proposal to add a new provision to prohibit shell collecting. Currently visitors may take up to six shells each provided an export permit is obtained (UNEP, 1984; Webb, undated). Spearfishing is prohibited and the government has called in all spearguns and harpoons from fishermen (Fagoonee *in litt.*, 1.1.86).

Six Fishing Reserves, in which large net or gill net fishing is prohibited, are defined under the Fisheries Act (1980) and detailed in Government Notice No. 18 of 1983: Black River, Flacq, Grand Port-Mahebourg, Port Louis, Riviere du Rampart-Poudre d'Or and Trou d'Eau Douce (*see separate accounts*). The restrictions are rarely enforced although the Protection Branch within the Fisheries Division is actively engaged in patrolling the lagoon, particularly around the Reserves.

There are no marine protected areas as such yet. The existing terrestrial protected areas were created under the Ancient Monuments Act of 1944 and jurisdiction and restrictions are outlined in the Forest and Reserves Act 1983, under which the Nature Reserves Board was set up (replacing the Ancient Monuments Board) (IUCN, 1987). The Ministry of Agriculture, Natural Resources and the Environment is responsible for the administration of Crown Lands and through the Forestry Service, administers and manages terrestrial nature reserves except the island reserves which are serviced and maintained by the Ministry of Fisheries. The following Nature Reserves include or are adjacent to coral reefs:

- Round Island (described in IUCN, 1987)
- Coin de Mire (Gunners Quoin) (described in IUCN, 1987)
- Ile aux Aigrettes (*see account for* Grand Port Mahebourg Fishing Reserve)
- Ile Marianne (*see account for* Grand Port Mahebourg Fishing Reserve)
- Ile aux Cocos (*see account for* Rodrigues)
- Ile aux Sables (*see account for* Rodrigues)
- Ile Plate (*see account with* Ilot Gabriel)
- Ilot Gabriel (*see account with* Ile Plate)

A turtle reserve was established by the fishing company on Ile du Nord in the Cargados Carajos Shoals (*see separate account*) in the 1960s.

D'Arifat (1983) and UNEP (1984) discuss other legislation relating to coastal issues, such as the Continental Shelf Act (1970), the Removal of Sand Act (1973) (prohibits removal of sand from anywhere other than specific quarries), and the Wildlife Act (No. 15 of 1983). The import of explosives is also banned. Under the Maritime Zone Act (1977), designated areas may be created for the protection of the marine environment and measures may be introduced for the prevention and control of marine pollution. Most of Mauritius, except the west coast, has been declared a planning area which means that a permit is required before any development takes place, and environmental considerations can therefore be taken into account (D'Arifat, 1983). Further details of land use legislation are given in UNEP (1984). Enforcement of all legislation is a major problem, but has recently been improved by increasing the number of coastguard officers (Fagoonee *in litt.*, 1.1.86).

A conservation education programme on marine life is currently being developed and under an IUCN project, booklets on marine animals are being produced for schools (Atchia, 1984; Michel, 1985). A "Wildlife Research and Conservation Programme" was drawn up jointly by the Government of Mauritius, the International Council for Bird Protection and the Jersey Wildlife Preservation Trust in 1984. Phase I, 1984-1985, Initiation and Integration, involves the development of logistical frameworks for effective conservation measures, legal aspects, tourism and education and the start of some habitat and species improvement and rescue. However, there is no directly reef-related project in this phase.

**Recommendations**

Since the early 1970s, large numbers of recommendations have been made for improving the marine protected areas system. These include recommendations resulting from an FAO sponsored survey (Robertson, 1974), a report by Scott (1973) and an IUCN/WWF survey (Procter and Salm, 1974). The following areas were recommended for protection:

1. Blue Bay/Le Chaland (Procter and Salm, 1974); Blue Bay recommended as a Marine Park by Robertson (1974) (*see separate account*).
2. Ile Plate/Ilot Gabriel complex (Procter and Salm, 1974). Ile Plate recommended as a Marine Park by Robertson (1974) (*see separate account*).
3. Baie de l'Arsenal/Pte aux Cannoniers (Procter and Salm, 1974); this area, with the hotel development at Trou aux Biches recommended as a Marine Controlled Area (*see below*) (Robertson, 1974). There is also a separate recommendation that Anse de Balaclava should be given Marine Park status (*see separate account*).
4. Seaward extension to Round Island Nature Reserve, to 20 m depth (Procter and Salm, 1974); recommended as a Special Marine Reserve by Robertson (1974); terrestrial aspects described in IUCN (1987).
5. Seaward extension to Coin de Mire Nature Reserve (Gunners Quoin), to 20 m depth (Procter and Salm, 1974); recommended as a Special Marine Reserve by Robertson (1974); terrestrial aspects described in IUCN (1987).

Robertson (1974) recommended the creation of a system of Marine Controlled Areas within which certain activities such as shell collecting, would be controlled, and which would be supervised by Fisheries Officers:

1. Le Morne Brabant: the lagoon has little coral but it is suitable for snorkellers and glass-bottom boats; corals improve towards the reef edge; there is extensive hotel development on the northern shore of the isthmus.
2. Flic en Flac: the area from the north part of the Baie du Tamarin to the north end of the reef at Flac village is coming under increasing tourist pressure;

dive sites are good on the reef crest and reef front but there is some siltation and coral is collected.

3. Arsenal/Pte Canonnier: *see above*.
4. Grande Baie: on the north-west coast and also subject to pressure from tourists; a submarine park has been suggested at Grande Baie for the dive site known as the "Aquarium"; this is an area off Pte d'Azure of low profile spur and groove reef formation, accessible only to divers.
5. Roches Noire/Poste Lafayette; Trou d'Eau Douce; and Ile aux Cerfs: (some of these lie within the fishing reserve; *see separate accounts*).

The recommendations in Robertson (1974) were not implemented as the authorities considered that there would be considerable opposition from fishermen (UNEP, 1984). Procter and Salm (1974) point out that fishing pressure at Baie de l'Arsenal is in fact low and that this would be an ideal place for the creation of Mauritius's first Marine Park. This is now considered a priority (although Robertson (1974) suggested that the Ile Plate area was a higher priority as, in the 1970s, it had better reefs and was under less tourist pressure). Procter and Salm (1974) and Robertson (1974) provided detailed recommendations for management, park regulations and legislation which are repeated in UNEP (1984). The Four Year Plan for Social and Economic Development, the definite statement of Government Policy for 1981-1985, is reported to contain outline proposals for three marine national parks (IUCN, 1987).

Other recommendations include: the creation of special marine areas around Ile aux Aigrettes and Ile Marianne, as buffer zones and to protect the rich molluscan fauna found there (UNEP, 1984) (*see account for* Grand Port-Mahebourg Fishing Reserve); the designation of Perle and Fregate Islands, in the Cargados Carajos Shoals, as Nature Reserves (UNEP, 1984) and Ile du Nord, Ile Paul, Ile Poulailler, Ile Puit à Eau, Petit Capitaine and Grande Capitaine as bird sanctuaries (Staub and Gueho, 1968); and the improvement of the existing Fishing Reserves, either through closing certain areas to fishing or by promoting some areas within the Reserves to Marine Park status (UNEP, 1984). It has been suggested that certain areas and lagoons should be closed to fishing or any form of human interference for at least two years, apart from limited monitoring activities, following which other areas would be closed on a rotational basis (Fagoonee *in litt.*, 1.1.86). UNEP (1984) provides a number of recommendations for improved protection of reef-associated species, including molluscs, corals, crustaceans and fish. Alternative building and construction materials must be found in order to decrease the impact of coral mining.

A draft programme for the development and protection of Mauritius' coastal and marine resources, particularly coral reefs, was drawn up in the course of a Regional Workshop for Coastal and Marine Management and Protection in East Africa and the Indian Ocean, held at the University of Mauritus in 1983 under the auspices of the South Carolina Sea Grant Consortium, IUCN, UNEP and the U.S. National Science Foundation (Davidson, 1983). Recommendations were made for projects including a survey of the status of coastal and marine resources, improvement in pollution control, contingency plans for oil spills and a marine education programme. Training of Marine Park personnel and baseline studies, particularly on pollution, are required. Robertson (1974) outlines a number of proposals for marine research projects. The University of Mauritius is carrying out projects relating to marine resources under its programme Mauritius 2000 (Manrakhan, 1983) and a project has recently been initiated with Unesco's support to study the status of Mauritian reefs (Fagoonee *in litt.*, 1.1.86). It is planned to use remote sensing and infrared imagery to map the reefs, lagoons and coastal systems.

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## BAIE DE L'ARSENAL PROPOSED MARINE NATIONAL PARK

**Geographical Location** West coast, north of Port Louis and just north of Anse de Balaclava; 20°06'S, 57°30'E.

**Area, Depth, Altitude** 100 ha.

**Land Tenure** Government owned.

**Physical Features** The bay has a sheltered environment, with infrequent currents and surf; the water is usually calm even during storms. The large size of many of the relatively fragile coral colonies suggests that the western aspect of the region shelters it from severe cyclonic conditions.

Basalt boulders line the shore, cemented basally by beach rock. Landward of this there are raised beaches, raised reef and dunes, providing a complex and interesting geological basis for the coral reefs (Pichon, 1971). Procter and Salm (1974) describe the raised fossil reefs and give a general description of the area. On the north of the brackish lagoon there is a fine grey sand beach. Running north of Pointe aux Piments there is a continuous coarse sandy beach of shell and coral grains. Several ledges of beach rock at Pointe aux Piments form a more or less continuous series of arcs parallel to the shore, some covered by sand and others in the lagoon, well forward of the beach. The southern shore has a small beach of coral fragments and three shelves of beach rock, two close to the shore and a third 30 m from the beach at its furthest point. The southern point of the bay has several fractured spurs of basalt impinging into the sea and creating a series of shallow pools. North across the bay there is a 3-4 m high headland of weathered basalt.

Three major types of reef are represented: a peripheral fringing reef, 30-60 m off shore to north and south of the mouth of the small River Citron continuing to the head of the bay; lagoon coral patches behind this, and sheltered fringing reef bordering the channel opposite the river mouth. At the river mouth seagrass beds flourish and extensive sandy areas exist. These are described by Procter and Salm (1974).

**Reef Structure and Corals** The outermost reefs have a shallow reef flat with few, small coral colonies. The seaward edge has a rudimentary spur and groove structure which is evidently not principally an algal construction, and which supports scattered corals. The shallow reef slope is dominated by *Millepora*, while deeper on the slope there is a high diversity of corals. The lagoonal side of the fringing reef has a continuous band of staghorn corals. The sheltered fringing reefs of this area are also *Acropora* assemblages. Towards the mouth of the river, where salinity fluctuates, *Porites* "boulder reefs" become conspicuous. The lagoon patch reefs are best in the north of the bay opposite Pointe aux Piments where they are composed of thickets of staghorn coral (Procter and Salm, 1974; Salm, 1976). More than 48 coral species were recorded from the bay.

**Noteworthy Fauna and Flora** Procter and Salm (1974) recorded 137 fish species. The Hawksbill Turtle *Eretmochelys imbricata* was reported from the bay in the early 1970s. Turtles used to nest on the beaches (Procter and Salm, 1974). The fish in the Anse de Balaclava are described by Harmelin-Vivien (1976).

**Scientific Importance and Research** Procter and Salm (1974) consider the Baie de l'Arsenal unique in Mauritius for its diversity of habitats and species.

**Economic Value and Social Benefits** Three fishermen based in the area operate on the deeper fore-reef slope. The area is close to the main centre of population in Mauritius and recreational activities are fairly important. There are modern hotels in Balaclava; the Pointe aux Piments beaches are suitable for swimming but the Balaclava beach is of little value to tourists (Procter and Salm, 1974). There is a well-preserved earthern fort.

**Disturbance or Deficiencies** Generally the overall impact on this area has been relatively small, although overfishing has been noted. The bay used to be called Baie aux Tortues, but turtles no longer use the beaches. In the early 1970s sand was mined from the limited dunes of the south and from both the beach and dunes of Pointe aux Piments (Procter and Salm, 1974) but the impact of this is not known.

**Legal Protection** None.

**Management** A plan for the management of the area is outlined in the Procter and Salm (1974) report, but this has not yet been implemented.

**Recommendations** The area was considered of highest priority for designation as a Marine National Park (Procter and Salm 1974); a separate recommendation has been made for the designation of Anse de Balaclava as a marine park. Procter and Salm (1974) recommended that the three resident fishermen should be allowed to continue fishing outside the bay but should be encouraged to stop fishing within the bay and perhaps take divers to the reef instead. Procter and Salm (1974), Robertson (1974) and UNEP (1984) give detailed suggestions for the management of the Park which include the establishment of mooring buoys, monitoring programmes, control of visitors and regulations on fishing and boat use. No action has yet been taken, but this area may become Mauritius' first Marine Park.

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## BLACK RIVER FISHING RESERVE

**Geographical Location** West coast of Mauritius around the estuary of the Black River; 20°22'S, 57°20'E. The area includes that part of the sea bounded by the coast at high water mark and the sinuosities of the reefs from Petit Vacoas, where the reefs meet the coast, to Point Lascars on the northern part of Black River Pass; a straight line from Point Lascars to Grand Pointe on the southern point of the pass (both Black River and Case Noyale being included in the Reserve), and a straight line drawn from Grand Pointe to the southern extremity of Point des Requins.

**Area, Depth, Altitude** From sea-level to the bed of the lagoon; 900 ha.

**Land Tenure** Public ownership.

**Physical Features** A lagoon environment with coral patches and reefs and sandy areas. The internal zone is covered by sandy beaches, rocky shores and mangrove stands (UNEP, 1984).

**Reef Structure and Corals** No information.

**Noteworthy Fauna and Flora** There are important mangrove stands in the reserve.

**Scientific Importance and Research** Fish stock assessment studies are underway. The Fisheries Research Centre is situated a few kilometres to the north (UNEP, 1984).

**Economic Value and Social Benefits** The area is used for recreation. All commercially exploited species are well represented and the Reserve is a good nursery area for mullet (Mugilidae), crab (Brachyura) and oysters (Ostreiidae) (IUCN, 1987; UNEP, 1984).

**Disturbance or Deficiencies** Hotel development, boating activities and illegal fishing in the area have been reported; silt deposit appears to be extensive (IUCN, 1987; UNEP, 1984).

**Legal Protection** Established as a Fishing Reserve on 2 February 1983 by Government Notice No. 18. The Fisheries Act of 1980 prohibits the use of seine nets, large nets or canard nets within Reserves.

**Management** Administered by the Protection Service of the Fisheries Division. Three fisheries assistants are posted in an adjacent fisheries post. Enforcement is carried out as part of the general duties of the Fisheries Protection Officers (UNEP, 1984).

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## BLUE BAY/LE CHALAND

**Geographical Location** South-east coast; area between Pointe Corps de Gard and Ile des Deux Cocos, off the village of Le Chaland.

**Area, Depth, Altitude** 390 ha of shallow water and reefs.

**Physical Features** The shoreline is principally basalt boulders cemented basally by beachrock. The peripheral fringing reefs are exposed to a considerable south-east swell; accumulated water flows with dangerous velocity through the pass between Le Chaland and Ile des Deux Cocos (Procter and Salm, 1974).

**Reef Structure and Corals** The reefs are described by Salm (1976). The western part of the bay has a coral bank and a fringing reef, dominated by staghorn *Acropora*, with an irregular front which merges with the coral banks; the reef flat has appreciable coral cover. North of this, or deeper into the bay, are several isolated patches of coral growing in deeper water. The eastern border has reefs with a greater diversity of corals, in particular, enormous hillocks of *Pavona* spp. with *Mycedium tenuicostatum* which is unusual in Mauritius. On the sandy substrate, *Goniopora* and *Porites* provide hard substrate for several other species, notably *Acropora* and *Pavona*. Large tabular *Acropora* corals are also conspicuous, and when dead or overturned, provide substrate for other colonizers. These patches have expanded and fused to provide the numerous, large coral banks found in the Bay. Only twenty-eight coral species have been recorded which is probably due to the uniform habitat. Further off shore lies a peripheral fringing reef. This has not been surveyed, and approach to it is difficult because of the south-easterly swell.

**Noteworthy Fauna and Flora** Ninety-one species of fish were recorded (Procter and Salm, 1974). The Bras de Mer du Chaland has a fringe of mangroves especially along the southern border.

**Scientific Importance and Research** No information.

**Economic Value and Social Benefits** There is a large sandy beach on the Blue Bay side which is popular with Mauritians and a smaller beach in the west in front of the Le Chaland Hotel; both are used for recreation. Blue Bay is a fairly major centre for tourists (Robertson, 1974). Fishing is an important activity with some 60 fishermen based in the area (UNEP, 1984).

**Disturbance or Deficiencies** This area has large amounts of litter, and has suffered damage from anchors. On the reef flat there is extensive damage from wading, boats and poles (Robertson, 1974; Salm, 1976). Robertson (1974) considered Blue Bay to have suffered less from overfishing than many other areas.

**Legal Protection** None.

**Management** None.

**Recommendations** The area has been recommended as a Marine Park (Procter and Salm, 1974), but no action has yet been taken (Owadally, pers. comm. to IUCN, 1983). Robertson (1974) provides detailed recommendations for the management of this area.

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## CARGADOS CARAJOS SHOALS (ST BRANDON ISLETS)

**Geographical Location** 16°23'S, 59°27'E, about 215 miles (346 km) NNE of Mauritius.

**Area, Depth, Altitude** Several thousand square kilometres in total although the total area of the reef probably does not exceed 190 sq. km; the islands do not exceed a very few metres in altitude; shoals are usually less than 20 m deep (Strauss pers. comm., 1984).

**Land Tenure** Leased to a private fishing company.

**Physical Features** This complex of low islands, coral reefs and sand banks arises from a vast shallow submarine platform. The main structure is a large, 100 km long crescent-shaped reef whose convex side faces towards the south-east trades and the South Equatorial Current. The reef front of the main reef recurves inwards at both ends and is cut by two or three passes. Behind the reef there is a vast area of shallows, sand banks and about twenty islets and cays. Some islets lie near the passes but the majority lie well to leeward of the main reef or on the southernmost recurved end. Many patch reefs lie amongst the several hundred square kilometres of shallow water and banks behind the main crescentic "backbone" (Faure, 1975).

The most northerly island is Albatros, which lies about 12 miles (19.3 km) north of the main reef on the rich fishing grounds of Grandes Carneaux, which link up 150 miles (240 km) further north with the Nazareth Banks, another important fishing area. To the north of Cargados Carajos itself lies Ile du Nord (St Brandon). St Raphael, (Establishment Island) lies at the northern end of the main reef, the main curve of which shelters Perle, Fregate, and Ile Paul in the central region, and a small chain of over a dozen islands at the southern end.

Temperatures are 23-26°C, with rainfall of 1050 mm a year, most falling in January to April. The climate is dominated by the south-east trades. Cyclones can cause considerable damage. In 1948, Ile aux Fous disappeared and Avoquer was submerged by 2 m of water. Petit Ile Longue was swept away in a later cyclone, but is now reappearing. The South Equatorial Current is dominant.

**Reef Structure and Corals** There are no detailed descriptions of the reefs. The main reef has a very broad reef flat, extending up to several hundred metres across in parts. At its seaward edge, it is characterized by a massive algal ridge (Gardiner, 1907; Strauss *in litt.*, 9.7.84) whose dimensions would appear to make it by far the largest such structure that has been reported for the Indian Ocean. Together with much of the broad reef flat it is emergent at low tides. Apart from calcareous red algae it supports a few pocilloporoid corals. The reef slope to seawards is described by Strauss (*in litt.*, 9.7.84) as largely devoid of live corals and with few fish. Down to at least 20 m depth the substrate is swept clear of attached biota, although on the sides of spurs or buttresses a few corals exist.

Underwater photographs of some of the numerous knolls and banks behind the reef show that the density of corals and soft corals is typical of many very sedimented areas and shallow lagoons in the Indian Ocean. Sedimentation and turbidity is so high in the lee of the main reef, due to floating and suspended organic matter (Strauss *in litt.*, 26.6.84), that visibility is reduced almost to zero in some places. The vast areas of sand which accumulate in the leeward platform suggest plentiful limestone production on and around the reefs and from the main seaward reef. Four scleractinian coral genera have been recorded from the shoals (Stoddart, 1984) but more will certainly be found.

**Noteworthy Fauna and Flora** The islands are home to vast numbers of seabirds (Feare, 1984; Gardiner, 1907; Strauss *in litt.*, 9.7.84). Staub and Gueho (1968) found a total of 26 species. Blue-faced Boobies *Sula dactylatra melanops* are found on Serpent Island and Ile du Nord. Large populations of Sooty Terns *Sterna fuscata* and White Terns *Gygis alba* occur on Albatros, St Raphael and Siren Islands. The islands were once important nesting sites for Green *Chelonia mydas* and Hawksbill Turtles *Eretmochelys imbricata*. The Coconut Crab *Birgus latro* may occur on the islets but there are no confirmed records. Cargados Carajos is reported to be the only place where the spider shell *Lambis violacea* has been found (Robertson, 1974).

**Scientific Importance and Research** Scientific visits were made by Gardiner (1907) and Staub and Gueho (1968), who provided historical notes and whose interest was mainly ornithological and botanical. An expedition including U.S. National Museum scientists visited the shoals in 1976 (Strauss *in litt.*, 26.6.84) and carried out mainly ichthyological studies, but provided the only data which is available on the reef biota. The algal ridge is an important feature of the shoals and appears to be the largest recorded for the Indian Ocean. Meteorological data has been recorded on St Raphael since 1944 and is of value in tracking Indian Ocean cyclones (Staub and Gueho, 1968).

**Economic Value and Social Benefits** The reefs are clearly very productive, and fisheries have long been important in the waters of Cargados Carajos. After the Portugese charted the islets in 1546 and called them Sao Brandao and Cargados Carajos, they were subsequently visited only occasionally, usually as a source of water. After the British replaced the French in Mauritius they were used increasingly by fishing companies and became noted for their large fish populations, Green and Hawksbill Turtles, and the lobster *Panulirus*. Their human population was always small, consisting principally of fishermen. Fishing remains the main commercial attraction of the area, although some of the larger islands have been planted for coconuts. Grandes Carneaux and Nazareth Banks are currently important fishing grounds. The private company which leases the islets exploits both the guano and the fishery resources. There is potential for tourism but this has not yet been developed (UNEP, 1984).

**Disturbance or Deficiencies** Before Gardiner's visit in 1901 some islands had already been exploited for guano (Gardiner, 1907) and after 1927 new owners renewed this activity while continuing with their fishing industry. Guano mining is an obviously detrimental activity on such small islands, although it does not have the same importance today. Turtles are threatened by overexploitation. Tern eggs are eaten by inhabitants.

**Legal Protection** A turtle Reserve was established at Ile du Nord by the Fishing Company in the late 1960s but presumably does not include the reefs. Landing on this island is permitted only in the summer (Staub and Gueho, 1968) under the Fishing Company's Regulation. Until 1983, there was a quota for the harvest of Green Turtles; since then capture of turtles has been prohibited (UNEP, 1984).

**Management** The Fishing Company is responsible for enforcement of both national and local regulations and to date management appears to have been quite good (UNEP, 1984).

**Recommendations** It is recommended that Perle and Fregate Island be designated Reserves by the Fishing Company (UNEP, 1984). The bird populations need urgent protection. Staub and Gueho (1968) recommended that Ile du Nord, Ile Paul, Ile Poulailler, Ile Puit à Eau, Petit Capitaine and Grand Capitaine be made Bird Sanctuaries. The advantages and disadvantages of the islands remaining under the control of the Fishing Company or coming under government control are discussed in UNEP (1984); whatever the case, the area is a high priority for Reserve status, which should extend to the marine environment.

## FLACQ FISHING RESERVE

**Geographical Location** Eastern coast of Mauritius; 20°9'S, 57°45'E; includes that part of the sea between the sea coast at high water mark and a line drawn from Point La Brise at Poste Lafayette to Pointe de Flacq.

**Area, Depth, Altitude** From sea-level to the bed of the lagoon; 600 ha.

**Land Tenure** Public ownership.

**Physical Features** This is a lagoon environment, with sandy and rocky bottom and coral reefs. There are numerous mud flats and sand banks, some with rocky outcrops, marshes and a barachois (fish pond) (UNEP, 1984).

**Reef Structure and Corals** No information.

**Noteworthy Fauna and Flora** Mangroves occur along much of the coast and on islets (UNEP, 1984).

**Scientific Importance and Research** Fish stock assessment studies are underway (UNEP, 1984).

**Economic Value and Social Benefits** All commercially exploited species are well represented. There are large nursery areas for mugilids (mullet), siganids (rabbitfish), lethrinids (emperors), mullids (goatfish) and the milkfish *Chanos chanos*. Knowledge of smaller taxa is generally lacking. *Mugil cephalus, M. sebeli*, and crabs *Scylla serrata* and many species of prawns (Penaeidae) occur which are highly valued for food. The area is also used for recreation (UNEP, 1984).

**Disturbance or Deficiencies** Hotel development, boating activities and illegal fishing may be affecting the environment (UNEP, 1984).

**Legal Protection** Established on 2 February 1983 by Government Notice No. 18. The Fisheries Act of 1980 prohibits the use of seine nets, large nets or canard nets within Reserves.

**Management** Three fisheries assistants are posted in an adjacent fisheries post. Enforcement is carried out as part of the general duties of the Fisheries Protection Officers. Administered by the Protection Service of the Fisheries Division (UNEP, 1984).

**Recommendations** The Roches Noires and Poste Lafayette area was recommended as a Marine Controlled Area by Robertson (1974).

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## GRAND PORT-MAHEBOURG FISHING RESERVE AND ILE AUX AIGRETTES AND ILE MARIANNE NATURE RESERVES

**Geographical Location** South-east coast around the port of Mahebourg; 20°23'S, 57°42'E: that part of the sea coast bounded by the high water mark and a straight line drawn from a stone bearing the letters "R.L." behind the Roman Catholic church at Old Grand Port to the extreme eastern point of Ile aux Aigrettes to the reefs and along the sinuosities of the reefs to the Ilot at le Broudou. Ile Marianne lies 7.4 km to the east of Vieux Grand Port (20°22'S, 57°47'E); Ile aux Aigrettes lies about 1 km east of Pointe d'Esny (20°25'S, 57°43'E).

**Area, Depth, Altitude** From sea-level to the bed of the lagoon; 2200 ha; Ile aux Aigrettes is 25 ha, max. alt. 4-5 m; Ile Marianne is 2 ha, max. alt. 1-2 m.

**Land Tenure** Public ownership.

**Physical Features** This is a lagoon environment with coral patches and reefs, sandy areas, a rocky bottom and an intertidal zone with sandy beaches and rocky shores. In some areas the intertidal zone is occupied by cliffed shores and eroded eolianite deposits. The area includes Ilot Chat, Ilot Rat and Mouchoir Rouge and is bordered by Ile aux Aigrettes and the islet at Le Bouchois, as well as the estuaries of Rivière La Chaux and Rivière des Creoles and a small portion of the barrier reef. Ile aux Aigrettes and Ile Marianne are composed of coralline dune rock with eroded coastlines (UNEP, 1984).

**Reef Structure and Corals** Faure (1977) describes the barrier reef, most of which lies outside the Reserve.

**Noteworthy Fauna and Flora** There are patches of mangroves and ferns in some areas and dense stands of mangroves in others; mangroves, normally harbouring significant areas of mud flats, are found in the upper limits of the intertidal zone. The sparse vegetation on Ile des Aigrettes is described in Johnson (1894) and UNEP (1984). The island is a nesting site for large numbers of migratory seabirds. The mollusc fauna around Ile Marianne is particularly diverse. Molluscs in this area are described by Henon (1976).

**Scientific Importance and Research** Fish stock assessment studies are under way. The Mahebourg fish farm, of about 83 ha, has laboratory and aquaria facilities (UNEP, 1984).

**Economic Value and Social Benefits** Fishing occurs in the area; all commercially exploited species are fairly well represented. Shell collecting is intensive around Ile Marianne (UNEP, 1984).

**Disturbance or Deficiencies** During heavy rains and cyclones the lagoon becomes silted. Illegal fishing takes place. Lime kilns at Mahebourg make use of large quantities of live coral. Ile aux Aigrettes is threatened by introduced rats and the removal of its vegetation. Ile Marianne has been a popular shell collecting site but it is not known what impact this has had on mollusc populations (UNEP, 1984).

**Legal Protection** Established as a Fishing Reserve on 2 February 1983 by Government Notice No. 18. The Fisheries Act of 1980 prohibits the use of seine nets, large nets or canard nets within Reserves. Ile aux Aigrettes was established as a Reserve on 30 November 1965; Ile Marianne was established as a Reserve on 4 December 1972 under the Ancient Monument Act of 1944.

**Management** Three fisheries assistants are posted in an adjacent fisheries post. Enforcement in the fishing reserve is carried out as part of the general duties of the Fisheries Protection Officers. Ile aux Aigrettes and Ile Marianne are administered by the Forestry Department (UNEP, 1984).

**Recommendations** Ile aux Aigrettes and Ile Marianne need a full time warden. It has been recommended that Special Marine Reserves be created around Ile aux Aigrettes and Ile Marianne on account of their rich mollusc life and to provide a buffer zone for the islands (UNEP, 1984).

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## ILE PLATE AND ILOT GABRIEL NATURE RESERVES

**Geographical Location** Off the north coast, about 11 km NNE of Cap Malheureux; Ile Plate is at 19°53'S, 57°39'E; Ilot Gabriel is at 19°53'S, 57°40'E.

**Area, Depth, Altitude** 420 ha of reef and island; Ile Plate is 253 ha, max. alt. 116 m; Ilot Gabriel is 42 ha, max alt. 27.5 m.

**Land Tenure** Islands under Public Ownership.

**Physical Features** Ile Plate is nearly circular in outline and about a mile in diameter. It consists of two main parts, a rocky hill on its southern extremity with a plateau of volcanic rock beneath it stretching northward and forming more than half the island. The eastern and western parts are formed of sand ridges some of which rise to 9 m above m.s.l. They stretch northward from the base of the hill and degrade into a mass of loose coral and finally into loose volcanic blocks. Below the hill, landward, the rising ground is formed of a thin stratum of volcanic soil and volcanic sand (UNEP, 1984).

Ilot Gabriel is the central portion of a volcanic mound which rises to about 90 ft (27 m) and is broken into ridges and boulders and covered with a thin layer of volcanic earth. It is bounded by low sand banks except at a point on the south-east where the beach is composed of long spurs of volcanic rock projecting into the sea. Toward the central portion, the shore sand intermixes with coral blocks and volcanic detritus which extends for a considerable distance forming a narrow belt to the central portion of volcanic rock (UNEP, 1984). The geology of both islands is described by Ayres (1860).

**Reef Structure and Corals** Procter and Salm (1974) and Salm (1976) describe the reefs. A continuous peripheral fringing reef joins the northern points of both islands. Waves break onto the reef, pumping water into the shallow lagoon area between the islands, which exits through a channel in the south. On its outer edge, the reef flat consists of rubble cemented by calcareous red algae, and supporting brown algae. Behind this is uncemented rubble, followed on the leeward side by broken *Acropora* corals. The lagoon behind the fringing reef is one to a few metres deep, almost covered with surface-reaching tabular *Acropora* corals and an abundance of the blue coral *Heliopora coerulea*. Large stands of foliaceous *Montipora* also occur. The uppermost tips of all the corals nearest the water surface are dead, probably as a result of heavy rainfall at low tide or by the surface layers of lagoon water warming above the corals lethal limit during hot calm weather. The entire north-west arm of the lagoon is a series of quiet calm pools with patches of corals, *Heliopora*, dense seaweeds and numerous fish.

The seaward reef slope of the southern fringing reef has a rudimentary spur and groove structure, but the reef is poorly developed, although it supports large populations of reef fish. This reef is fairly broad, but is not continuous between the two islands.

**Noteworthy Fauna and Flora** Vegetation of both islands is described in UNEP (1984) and an early description is given in Horne (1887). Skinks and lizards are present but neither islet is important for birds (UNEP, 1984) although Newton (1956) reported that White-tailed Tropicbirds *Phaeton lepturus* and Red-tailed Tropicbirds *P. rubricauda* bred on Ilot Gabriel at one time. The reefs have an unusually large number of molluscs and large fish still surviving and 150 species of fish have been recorded (Procter and Salm, 1974).

**Scientific Importance and Research** The lagoon between the two islands is unique amongst the reefs of Mauritius for its abundance of blue coral *Heliopora coerulea* (Salm, 1976).

**Economic Value and Social Benefits** About 127 fishermen are dependent on this area for their income (UNEP, 1984).

**Disturbance or Deficiencies** The lagoon area contains much broken coral caused by dynamiting, boat anchors and boat grounding (Salm, 1976). Rabbits, rats and cats are numerous on the islands (UNEP, 1984).

**Legal Protection** The reefs have no legal protection. Ile Plate was established as a Reserve 15 July 1972; Ilot Gabriel was established as a Reserve on 4 December 1972 under the Ancient Monument Act of 1944.

**Management** The islands are administered by the Forestry Department, Ministry of Agriculture, Fisheries and Natural Resources, Curepipe and are visited as often as possible by Forestry Service, Fisheries and Port Officers.

**Recommendations** The reefs were recommended for Marine Park status (Procter and Salm, 1974; Robertson, 1974; Salm, 1976), but have not yet been declared as such (Owadally pers. comm. to IUCN, 1983). Robertson (1974) provides particularly detailed recommendations with suggestions for the boundaries and proposals for research and monitoring to be carried out in the area.

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## PORT LOUIS FISHING RESERVE

**Geographical Location** North-west coast near Port Louis; 20°09'S, 57°23'E: that part of the sea between the sea coast from high water mark and a line drawn from Martello Tower at Pointe aux Sables to a point due west on the reefs and from "Pointe Tortue" along a straight line to the most westerly point at Fort George.

**Area, Depth, Altitude** From sea-level to the bed of the lagoon; 500 ha.

**Land Tenure** Public ownership.

**Physical Features** The area includes the harbour of Port Louis and an estuary at the entry of the Grand River North West and River St Louis. The lagoon substrate is muddy to sandy with coral patches of mostly dead communities. A deep channel leads to the main harbour of the island from a wide pass in the reef which also consists of mostly dead communities (IUCN, 1987; UNEP, 1984).

**Reef Structure and Corals** Corals in the area are largely dead.

**Noteworthy Fauna and Flora** Fish are abundant in the lagoon, particularly siganids (rabbitfish) and parrotfish (Scaridae). Other commercially exploited species include crab. Seagrass communities are extensive in the southern part.

**Scientific Importance and Research** Fish stock assessment studies are carried out; a Fisheries Research Centre is situated 10 km to the south (UNEP, 1984).

**Economic Value and Social Benefits** Fishing occurs in the area.

**Disturbance or Deficiencies** Effluents (including industrial waste) from two sewage outfalls may be causing eutrophication which is contributing to the extensive growth of seaweeds (*Ulva lactuca, Eucheumia* sp., *Enteromorpha* sp.) around the outfalls. Solid waste dumping occurs around Northern Point and there is pollution from the harbour. Illegal fishing is common in the reserve (UNEP, 1984).

**Legal Protection** Established on 2 February 1983 by Government Notice No. 18. The Fisheries Act of 1980 prohibits the use of seine nets, large nets, or canard nets within Reserves.

**Management** Administered by the Protection Service of the Fisheries Division. Three assistants are posted in an adjacent fisheries post. Enforcement is carried out as part of the general duties of the Fisheries Protection Officers.

## RIVIERE DU RAMPART-POUDRE D'OR FISHING RESERVE

**Geographical Location** North-east coast; 20°05'S, 57°42'E; that part of the sea between the sea coast from high water mark and a line drawn from Pointe Grand Courant to the nearest shore of Ile d'Ambre and along the shore of that island to Pointe Dejeuner, thence along a prolonged line to the southern side of Passe St Geran and along the reef to Point Roches Noires.

**Area, Depth, Altitude** From sea-level to the bed of the lagoon; 3500 ha.

**Land Tenure** Public ownership.

**Physical Features** This is a lagoon environment with sandy and rocky bottoms, coral reefs, and an intertidal zone covered by small stretches of sandy beaches. Rocky shores predominate and there is an area of fringing reef and two barachois (brackish ponds) (UNEP, 1984).

**Reef Structure and Corals** No information.

**Noteworthy Fauna and Flora** The area is particularly rich in mugilids (mullet), siganids (rabbitfish), mullids (goatfish) and lethrinids (emperors). All the commercially exploited species are fairly well represented. Rich oyster beds are present. Mangroves are found interspersed with rocky shores and in some areas form dense stands, and also top numerous rocky islets (UNEP, 1984).

**Scientific Importance and Research** Fish stock assessment studies are under way (UNEP, 1984).

**Economic Value and Social Benefits** Fishing occurs in the area and fish and oyster farms are present. The area is not considered to have good recreational amenities but Robertson (1974) recommends it for research.

**Disturbance or Deficiencies** Illegal fishing take place in the reserve. An outbreak of urchins caused overgrazing of seagrass beds in the early 1970s (UNEP, 1984).

**Legal Protection** Established as a Reserve on 2 February 1983 by Government Notice No. 18. The Fisheries Act of 1980 prohibits the use of seine nets, large nets, or canard nets within Reserves.

**Management** Administered by the Protection Service of the Fisheries Division; three assistants are posted in an adjacent fisheries post. Enforcement is carried out as part of the general duties of the Fisheries Protection Officers (UNEP, 1984).

## RODRIGUES, INCLUDING ILE AUX SABLES AND ILE AUX COCOS NATURE RESERVES

**Geographical Location** The most north-easterly of the Mascarene Islands. Ile aux Sables (19°43'S, 63°17'E) and Ile aux Cocos (19°42'S, 63°18'E) lie 3.7 km north-west of Pointe La Fouche in the west.

**Area, Depth, Altitude** Island is 109 sq. km; reefs about 200 sq. km. Ile aux Sables 7.75 ha; max. alt. 2 m; Ile aux Cocos 14.4 ha, max. alt. 4 m.

**Land Tenure** Formerly a dependency, now a part of Mauritius. The Nature Reserves are under Public Ownership.

**Physical Features** Rodrigues, the smallest of the Mascarene Islands, is of volcanic origin and consists of sub-horizontal basaltic runnings (Faure, 1975; Montaggioni, 1976). After a period of active volcanism, the island is supposed to have been subjected to marine erosion which gave it the form of a guyot. Later volcanic eruptions produced more basaltic flows which formed most of the present littoral substrate. In the recent Quaternary the east and south-east parts of the island were the centre of important aeolian activity which resulted in dune rock being formed on the basaltic substrate. A general description of the island is given in Gade (1985).

Tides are semi-diurnal with a diurnal inequality. Spring-tides have an amplitude of 1.2 m which is greater than in the other Mascarene Islands. Rodrigues is influenced by the South Equatorial Current and the south-east trade winds, and is within an area of cyclonic activity. Temperatures often exceed 30°C.

A wide expanse of reef platform extends without a break for 90 km around Rodrigues, most markedly towards the west. The reef flat extends 1 or 2 km from land in the east of the island (though sometimes as little as 50 m) and as much at 10 km in the west. As with many reef expanses of this size, it is cut by several channels of various origins and dimensions, some of which are open and some of which are partly occluded by sand and coral knolls. Emerging above the level of the reef flat are several small islands, some of which are basaltic like the main island, and others of which are sand cays, such as Ile aux Cocos and Ile aux Sables which lie on either side of Passe Demie in the west (UNEP, 1984).

**Reef Structure and Corals** Several transects across the reef slope and reef flat are described and illustrated by Montaggioni and Faure (1980). Extensive parts of the flat are colonized by seagrasses, especially *Halophila* which is found around Port Sud-Est and the north central expanse, where the maximum depth of the reef flat over its entire width is about 1 m. Over much of the rest of the reef flat there are extensive areas of sand and rubble, with sparse colonies of corals. Occasional shallow channels cut about 1 m deep into the reef flat, running parallel to the shore as well as perpendicularly to it; such channels also occur around the small offshore islands. There is increasing coral cover towards the outer edge of the reef flat. The zone termed the "platier necrose" supports much dead coral, originating largely from the branching coral zone, composed mostly of *Acropora*, which is immediately to seaward of it. The reef flat is compact at its outer edge, and then descends fairly steeply at most points around the island. Coral cover on steeper areas commonly exceeds 50-70%. Brain and encrusting forms are generally most common although in several areas soft corals are dominant.

A study of the main channels and discontinuities of the large reef flat was carried out by Faure (1974 and 1975). These structures break the otherwise continuous nature of the reef flat in several places. One, the Grande Passe de Port Sud-Est, 40 m deep and 200 m wide, stretches 2.5 km from land to the outer edge of the reef flat. At its landward end it is connected with a back-reef channel which runs along the coast from east to west. The upper regions of its walls are dominated by soft corals, but stony corals increase in abundance at greater depths where they provide substantial cover. Below a depth of 30 m, the channel walls have the appearance of stepped benches, often covered by coral debris from above and supporting successively fewer corals. At 35-40 m depth the floor of the channel is covered by rubble and sand or outcrops of bare rock. Other passes have a similar zonation. One feature of interest which is common to all of them (and indeed to many passes throughout the Indo-Pacific) is the displacement of deeper water corals into the shallows, including asymbiotic species. Faure (1975 and 1976) compares the reefs of Rodrigues with those of Mauritius and Reunion.

**Noteworthy Fauna and Flora** The vegetation and avifauna of Ile aux Cocos and Ile aux Sables are described in UNEP (1984). Ile aux Cocos has large colonies of Brown *Anous stolidus pileatus* and Lesser Noddies *A. tenuirostris tenuirostris* (4000-7000 of each), and about 400 White Terns *Gygis alba*. Ile aux Sables has smaller colonies of the same three species. The Hawksbill Turtle *Eretmochelys imbricata* was once common around Rodrigues and Ile aux Cocos but is now rare (UNEP, 1984).

**Scientific Importance and Research** Rodrigues has the most substantial and best developed reefs in the Mascarenes (Montaggioni and Faure, 1980).

**Economic Value and Social Benefits** The small islands are visited by tourists.

**Disturbance or Deficiencies** Birds on Ile aux Sables and Ile aux Cocos have been seriously disturbed by egg collectors (UNEP, 1984). Corals are used for construction (Fagoonee *in litt.*, 1.1.86) but it is not known to what extent this causes damage. There has been extensive deforestation on the island which has led to siltation on the reef and has probably also contributed to the noticeable decline in reef fish catches (Gade, 1985).

**Legal Protection** Ile aux Cocos and Ile aux Sables were established as Nature Reserves on 30 May 1981 under the Ancient Monuments Act (1944). Visitors to the islets require a permit (UNEP, 1984).

**Management** Administered by the Forestry Department. There is a warden on Ile aux Cocos and the islets are visited by Fishery and Forest Service Officers from Rodrigues.

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## TROU D'EAU DOUCE FISHING RESERVE

**Geographical Location** East coast; 20°16'S, 57°47'E: that part of the sea bounded by the sea coast from high water mark and a line drawn from the old lime kiln at Le Morne to the extreme western point of Ile aux Rats, then along the inner shore of the several Ile aux Cerfs to Pointe Petit Vacoas, then to the extreme point of Ilot Lievre and to Point Saint Lain, commonly known as Pointe Cassis.

**Area, Depth, Altitude** From sea-level to the bed of the lagoon; 700 ha.

**Land Tenure** Public ownership.

**Physical Features** No information.

**Reef Structure and Corals** There are varied coral communities and extensive areas with abundant *Pavona* and *Fungia*. There is considerable run-off from the land and the coral fauna found here tends to be tolerant of sediment and high salinities (UNEP, 1984).

**Noteworthy Fauna and Flora** There are extensive mangrove areas in the intertidal zones and around many small islets of the Ile aux Cerf region. The Reserve is rich in seagrass communities. Most of the shallow area is brackish, including the estuaries at the Grand River South East, and provides habitat for communities of oysters, which settle especially on the mangrove roots. The nursery area is particularly rich in mullet (Mugilidae) species (UNEP, 1984).

**Scientific Importance and Research** There is a laboratory at the shrimp hatchery (UNEP, 1984). Robertson (1974) recommends this area for monitoring and comparative studies.

**Economic Value and Social Benefits** Fishing occurs in the area. Robertson (1974) reported only limited hotel development.

**Disturbance or Deficiencies** Large amounts of silt are deposited in the Reserve during heavy rain. Pollutants from a sugar mill are carried via the Deep River Beau Champ to part of the Reserve which abounds with juvenile mullet. Illegal fishing has been reported (UNEP, 1984).

**Legal Protection** Established as a Fishing Reserve on 2 February 1983 by Government Notice No. 18. The Fisheries Act of 1980 prohibits the use of seine nets, large nets or canard nets within Reserves.

**Management** Administered by the Protection Service of the Fisheries Division. Three fisheries assistants are posted in an adjacent fisheries post. Enforcement is carried out as part of the general duties of the Fisheries Protection Officers.

**Recommendations** Robertson (1974) believes the reefs need little special attention but suggests that the area should be protected primarily for research purposes. Trou d'Eau Douce and Ile aux Cerfs were recommended as Marine Controlled Areas.

# MOZAMBIQUE

## INTRODUCTION

### General Description

Mozambique, between latitudes 10°20'S and 26°50'S, is generally lower lying than the other East African countries. The continental shelf along much of the 2500 km long coastline is very narrow but widens in the central part to 130 km off Beira (Bight of Sofala). Ninety per cent of the coastline consists of a low coast plain of sand or mud stabilized by plants, the remainder, mostly in the north, being coral rock. The coastline is deeply indented from the Rovuma River south to Mocambo Bay, with low coral rock headlands forming rugged cliffs 3-8 m high. The continental shelf here is very narrow, plunging to 2500 m depth within 30 km of the coast at Nacala. There are abundant fringing reefs. Further south the coast is dominated by dunes, swamps or deltas and reefs are found only on offshore islands. The geology of the coastline is described by Tinley (1971).

Tides are semi-diurnal to mixed (mainly semi-diurnal) with maximum ranges of about 3 m, which is above average for coral reef shores. Surface temperatures range from 22° to 27°C. The climate is tropical humid to sub-humid with little rain in the winter dry season. North of the Zambezi, precipitation is strongly influenced by the southern end of the East African Monsoonal System; south of the Zambezi, it is influenced by the Indian Ocean Sub-tropical Anticyclone System of the South-east Trade Wind Zone. Both systems overlap on the central coast between Beira and Pebane, where rainfall is very high. The coast is subject to the effect of high velocity storm winds which cause major shoreline changes over relatively short periods (Couper, 1983; UN/Unesco/UNEP, 1982). Tinley (1971) decribes the dynamics of the coast and provides further details on the climate.

The South Equatorial Current branches at the northern part of the Mozambique coast and the warm southern flowing branch, the Mozambique Current, is the main influence (Couper, 1983; Tinley, 1971). The coast is relatively well protected from open Indian Ocean wave action by Madagascar and as a result, there is considerable deposition and longshore transport of the river-derived sediments. Twenty five river systems exert a strong control on reef distribution and development, and relatively few parts of the coast are free enough from their influence for vigorous coral growth. The Zambezi River in the central region is the largest and discharges 15 000 - 20 000 cu. m/s of freshwater into the sea in the rainy season (January to March). Other important rivers are the Rovuma and Lurio in the north, several (Pungue, Busi, Gorongose and Save) which enter the Bight of Sofala in the middle of the coast, and the Limpopo, Incomati and Maputo which discharge into the Bay of Maputo (Bight of Lourenço Marques). Aside from the influence of freshwater, heavy sediment loads have created muddy areas and sediment banks off shore, causing expansion of deltas and, in several cases, of mangroves and swampy areas (Tinley, 1971). Mangrove forests cover 500 000 ha (Forjaz, 1985).

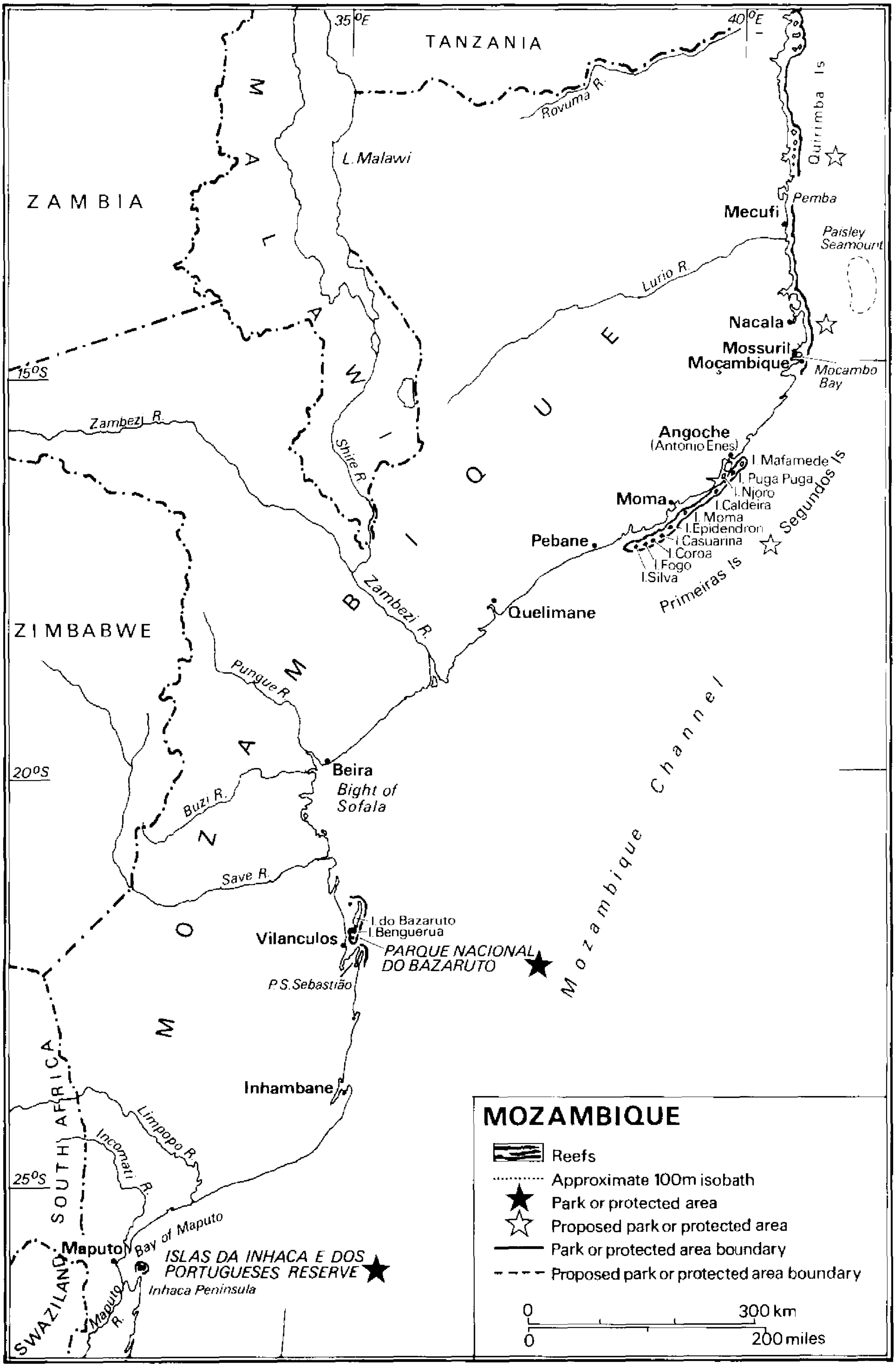
Little detailed information exists on the reefs of Mozambique with the exception of Inhaca Island (*see separate account*). Owing to the narrow continental shelf, coral formations are found only fairly near the coast. Fringing reefs are confined to the northern coast and extend south to Moçambo Bay (15°09'). North of Angoche (Antonio Enes), reefs are common close to the mainland and become more extensive and shallower towards the north. Small islands lying close to the islands become a more common feature, fringing reefs around them often linking up with coral reefs from the mainland. From Pemba (Porto Amélia) northwards, the islands are almost continuous, some reaching substantial sizes. Rich reefs are said to occur at Pinda, off the peninsula south of the Lurio River, and between Pemba and Mecufi (Tinley, 1971). Islands are much more common along this northern stretch; the barrier shoal from Moma to Angoche has two strings of small islands - the southern string known as the Primeiras and the northern as the Segundos (*see separate account*).

From Moma southwards to the South African border, rocky reefs with scattered corals are extensive but at only a few places are they attached to islands or the mainland, most occuring off shore at 3-30 m depth. South of Pebane, there are few islands; those that exist such as in the Bazaruto Archipelago and Inhaca Island are relatively large and were once part of the mainland. The largest gap in coral distribution is in the Bight of Sofala with its broad shallow continental shelf and turbid waters (Tinley, 1971; Werger, 1978). Inhaca Island is reported to be the southernmost coral reef of the African mainland (Boshoff, 1958), although coral communities extend southwards into South Africa (*see this volume*).

Five species of marine turtle nest along the Mozambique coast, mostly on offshore islands. The Hawksbill, Green, and Loggerhead Turtles (*Eretmochelys imbricata, Chelonia mydas* and *Caretta caretta*) are commonest on the islands. The Olive Ridley *Lepidochelys olivacea* has significant sporadic nesting (500-1000 nest annually) on the north coast. Less than 50 Leatherback Turtles *Dermochelys coriacea* nest annually (Groombridge, 1982; Hughes, 1971a, b, 1972 and 1981). The Dugong *Dugong dugon* occurs but has declined considerably (Hughes, 1971a and 1972; Tinley, 1970 and 1971). Marine fish are abundant and about 50 endemic species had been described by 1950 (Smith, 1950; Tinley, 1971). Molluscs are abundant on the reefs and rare species include *Conus pulicarius, C. bullatus, C. achatinus, C. legatus, Cypraea marginalis, C. beckii, C. contaminata, Phalium fimbria, Laevicardium aeolicum, Murex clavus* and *Cymatium ranzanii* (Tinley, 1971).

### Reef Resources

Three-quarters of the human population (approximately 4 million) live within 40 km of the coast, but few live on the immediate coastal strip because of the limited agricultural potential of the soils (UNEP, 1982). Artisanal fisheries are important (Tinley, 1971). Tourism


TANZANIA
ZAMBIA
MALAWI
ZIMBABWE
SOUTH AFRICA
SWAZILAND
MOZAMBIQUE
35°E
40°E
15°S
20°S
25°S
Rovuma R.
L. Malawi
Quirimba Is
Pemba
Mecufi
Paisley Seamount
Lurio R.
Nacala
Mossuril
Moçambique
Mocambo Bay
Zambezi R.
Shire R.
Angoche
(Antonio Enes)
I. Mafamede
I. Puga Puga
I. Njoro
I. Caldeira
I. Moma
I. Epidendron
I. Casuarina
I. Coroa
I. Fogo
I. Silva
Segundos Is
Primeiras Is
Moma
Pebane
Quelimane
Zambezi R.
Pungue R.
Mozambique Channel
Beira
Bight of Sofala
Buzi R.
Save R.
I. do Bazaruto
I. Benguerua
Vilanculos
PARQUE NACIONAL DO BAZARUTO
P.S. Sebastião
Inhambane
Limpopo R.
Incomati R.
Bay of Maputo
Maputo
ISLAS DA INHACA E DOS PORTUGUESES RESERVE
Inhaca Peninsula
Maputo R.
MOZAMBIQUE
Reefs
Approximate 100m isobath
Park or protected area
Proposed park or protected area
Park or protected area boundary
Proposed park or protected area boundary
0
300 km
0
200 miles

was once important, particularly at Paradise Island in the Bazaruto Archipelago, and is expected to become so again (Forjaz, 1985).

**Disturbances and Deficiencies**

Despite the limited agricultural activities in the area, terrestrial erosion may be leading to increased sedimentation and lowered productivity on the reefs. Other threats include pollution from a variety of sources such as agriculture (fertilizers, pesticides and herbicides) and industrial effluents, which already cause discolouration of water adjacent to factories. The proposed construction of a pulp factory complex in the Central Region (Villa Perry), with effluents flowing into the Busi River drainage whose water is used in Beira, could affect the important coastal fisheries and the nearby reefs (Tinley, 1971) but it is not known if this was built. The planned oil-related industry may become an important threat to the narrow continental shelf. Spearfishing and the stripping of reef flats is significant. Marine curios were collected in fairly large numbers from the reefs on the northern coast in the 1960s (Tinley, 1971) and turtle and shell products are currently on sale in Maputo, Beira, Nampula and Nacala (Tello, 1986). Fishing with explosives is not appreciable but does occur (Salm, 1983; UNEP, 1982). Overexploitation of marine turtles occurs despite protective legislation (Hughes, 1971a).

**Legislation and Management**

Parks and reserves are established under Decree No. 40040, 20 January 1955. There are six categories of protected area: Parques nacionais (national parks), Reservas especiais (game reserves), Reservas parciais (partial reserves), Regimen de vigilancia (faunal reserves), Coutadas (areas set aside for hunting and photographic safaris) and Reservas florestais (forest reserves). The Ministry of Agriculture is responsible for their administration, apart from Ilhas de Inhaca which is managed by the University Eduardo Mondlane. National parks are managed for ecological, cultural, aesthetic and socio-economic objectives; game reserves are similar but exclude the socio-economic objective; faunal reserves have one or more species protected although others may be excluded. Recently, multiple use areas have been defined and are managed by a parastatal organisation, Emofauna E.E., under the Department of Wildlife and Forestry, as wildlife and production areas. At present there are no marine areas under this category (IUCN, 1987).

Mozambique has 51% of the total protected coastal areas of East Africa, much of which is mangrove, marsh and dune (Salm, 1983). Parque Nacional do Bazaruto and Ilhas da Inhaca e dos Portugueses Reserve (*see separate accounts*) have significant reef systems. Other coastal protected areas in Mozambique are Reserva do Pomene (dugong, turtles, mangroves), Reserva especial do Marrameu and Reserva especial do Maputo (turtles, mangroves) but these areas do not have reefs.

Coral protection is under the control of the Instituto Investigacao Cientifico de Mocambique, and various Port Captains. There is no information on the extent of enforcement of legislation. Marine turtles, their eggs and young are protected under Article No. 2627, 7.8.65, superceded by the Hunting Law (Designation No. 7/78 of 18.4.78) and Decree No. 117/78 of 18.5.78 but enforcement is a major problem (Hughes, 1971a and 1981).

**Recommendations**

A proposal for a system of coastal zone planning and management has been drawn up and submitted for funding. A two-year programme has been formulated which has the support of the Secretaria de Estado de Planeamento Fisico (SEPF) which will provide management, and the assistance of the University Eduardo Mondlane (UEM) and various government ministries. National policies and appropriate legislation for management of coastal development and conservation will be developed. A development plan for the southern district of Mozambique and a pilot project management plan for Inhaca Island will be drawn up. Resource maps for the entire Mozambique coast will be produced and core areas for strict protection, buffer zones and areas for economic use (particularly tourism) and subsistence use, will be delineated. Training materials will be produced and courses on coastal survey methods, analysis and planning will be held for Mozambicans at the National Institute for Physical Planning, the Marine Station at Inhaca and the University Eduardo Mondlane. The project will be coordinated with other initiatives in UNEP's East Africa Regional Seas Programme (Forjaz, 1985).

Tinley (1971) recommended that a strip at least 100 m wide on low coasts and several kilometres in the high dune sectors should be kept free of buildings, roads and any other activity which could potentially be deleterious. An integrated scientific programme of ecological monitoring and research should be formulated and conservation education programmes should be a priority. A detailed set of general recommendations is given (Tinley, 1971) which may well still be relevant to the current coastal zone management plan.

The Primeiras and Segundos Islands between Moma and Angoche have been recommended as a Marine National Park and the islands of the Quirimba Group have been recommended as a protected area (*see separate accounts*). The area between Nacala and Mossuril on the north coast, to include Quitangonha Island, an important bird nesting site, has been proposed as a Marine National Park (IUCN/UNEP, 1984; Tinley, 1971) and includes coral reefs. It has been proposed that the Maputo National Park should be extended south to the South Africa border. Bazaruto Island has been proposed as a reserve for turtle and dugong (IUCN, 1987). The Paisley Seamount is situated off shore and is an important fishing ground; although not currently threatened it is recommended for protection on account of its importance, as one of two sites in the region with sabellariid reefs (IUCN/UNEP, 1984).

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## ILHAS DA INHACA E DOS PORTUGUESES RESERVE

**Geographical Location** The southernmost islands of Mozambique situated 25 km east of Maputo; approx. 26°S, 33°E.

**Area, Depth, Altitude** Ilha da Inhaca about 9 x 15 km; Ponta Torres Reef approximately 1 km long, 7-10 m wide; maximum depth 2-3 m.

**Physical Features** Ilha da Inhaca is irregularly-shaped and is formed of Quaternary to Recent dune sands overlying Pleistocene dune rock. It was once a peninsula which was subsequently severed and isolated along with its continental flora and fauna by the sea and/or wind action (Tinley, 1971). The two main coral reefs are Barreira Vermelha, off the western shore, and Ponta Torres Reef, in the south. The latter has been described in some detail by Salm (1976). It is sheltered from the shore by a belt of seagrass 20 m wide, to shoreward of which is exposed rock, before a zone of dune vegetation. A detailed description of the island is given in MacNae and Kalk (1958). Ilha dos Portugueses lies just to the north of Inhaca.

**Reef Structure and Corals** Despite its southernmost extremity, 35 hermatypic genera have been recorded from Ilha da Inhaca (Boshoff, 1958). Corals on the rocky fringing reefs, off the east side of the island, are the typical robust or encrusting species characteristic of this high energy Indian Ocean coast. Leeward of the island the sandy substrate is colonized by *Porites* which may form large heads. Rocky substrates are covered by luxuriant growth of branching and tabular *Acropora* species (Salm *in litt.*, 3.11.86). The reef at Ponta Torres is rudimentary, and the coral succession is clearly related to the reef's present form and expansion. It shows a cyclic pattern of primary succession, alternating with dissolution and a wave of secondary succession to a climax state. Expansion over soft substrate is initiated by *Porites* and sometimes *Goniopora* colonies which are able to live on the soft substrate. These grow and coalesce, eventually providing a cover of 56%, when cover by other genera is no more than 5%. The structures built by these pioneering corals are used as a substrate by other genera, until a total coral cover of 43% is reached, with high coral diversity, especially of the genera *Acropora, Echinopora, Platygyra* and *Pocillopora*. At intervals there is evidence of catastrophic destruction and interruption of this sequence, but secondary succession again reaches a climax stage once all the exposed, dead coral is covered by living colonies. As a result the reef is advancing slowly into the channel. At its southern end, the reef tapers off to a series of large coral heads, until finally there are isolated colonies of corals attached to old dune rock (Salm, 1976).

**Noteworthy Fauna and Flora** The island has tropical, sub-tropical and temperate species, a wide variety of Indian Ocean habitats and probably Mozambique's last remaining intact dune forest (Forjaz, 1985). The Loggerhead *Caretta caretta* and the Leatherback Turtles *Dermochelys coriacea* nest in the area (Hughes, 1971a and b) and may nest on Ilha da Inhaca. Molluscs are described by MacNae and Kalk (1958) and Moura (1969). They occur in great numbers and variety and include such rare species as *Cymatium ranzanii* and tridacnid clams (Salm *in litt.*, 3.11.86). Flamingoes nest at two sites and feed in the shallows near the mangroves. Mangroves and sandflats are described by MacNae and Kalk (1962 and 1966). The island is surrounded by extensive dense seagrass beds (Salm, *in litt.*, 3.11.86).

**Scientific Importance and Research** Ilha da Inhaca has the most southerly coral reefs of the East African coast (Salm, 1976 and 1983). The coral genus *Horastrea* has been recorded (Pichon, 1971), a restricted genus which otherwise occurs only on some of the large islands in the South-west Indian Ocean (Hamilton and Brakel, 1984). Ilha da Inhaca is also notable for its sabellarid reefs.

The variety of littoral and sublittoral habitats and the abundance and diversity of associated species have for decades attracted researchers and teachers with groups of students. Consequently the environments and biota of the island system have been thoroughly studied and documented. The University Eduardo Mondlane has run a well maintained research station (Estaçao de Biologia Maritima) on Ilha da Inhaca since 1953 (IUCN/UNEP, 1984). Since 1979, a marine biologist has been resident on the island with a number of administrative and technical staff (Forjaz, 1985). Current research includes studies on echinoderms and other marine invertebrates, a survey of corals at Ponta Torres and Barreira Vermelha and basic work on inshore waters. There is a museum which is open to the public. The resources, the data base, the research station, and its proximity to Maputo, make this an extremely valuable site for education and research.

**Economic Value and Social Benefits** In the past it was a very popular tourist attraction (Forjaz, 1985) and it still retains potential for domestic recreation and foreign tourism. There is an active fishing community on the island and another on the adjacent mainland (Salm *in litt.*, 3.11.86).

**Disturbance or Deficiencies** The small size of the Ponta Torres reef makes it especially vulnerable. The sand dunes south-east of the reef, which formerly were stabilized by vegetation, have been denuded by goats. In the 10 year period to 1968, strong southerly winds moved unconsolidated sand in a north-westerly direction towards the reef at a rate of 40 m a year and by 1976, water circulation across the reef had almost been prevented (Salm, 1976). The human population on land adjacent to the reserve has grown from 3000 to 7000 causing acute subsistence problems, degradation of the environment and encroachment of the reserve area itself.

There is uncontrolled access to the reserve. Threats to the environment include attempts to grow food in "muchangos", overuse of ground water, intensive collection of shellfish from tidal flats, overfishing, illegal collection of fuelwood and anchor damage (Forjaz, 1985). The reefs were reported to have been severely damaged through uncontrolled tourism in the early 1970s (Heydorn, 1972) and this could become serious again. Proposals have been drawn up for hotels inside and outside the reserve and other tourist facilities, such as SCUBA diving and water skiing. Additional potential threats include the proximity to Maputo Harbour and pollution sources and conflict between fisheries and tourism activities and conservation. The complex administrative structure with different bodies having partial and overlapping responsibilities for specific aspects of the island also poses a problem (Forjaz, 1985).

**Legal Protection** Designated a fauna protection area in 1965 (Forjaz, 1985). Some animal species and corals are protected (Tinley *et al.*, 1974). A decree passed in 1976 extended the reserve and improved management (Forjaz, 1985).

**Management** Administered by the University Eduardo Mondlane for conservation and education (IUCN, 1987) and theoretically managed by staff of the Marine Biology Station, although this has proved difficult. The dunes have now been replanted and are apparently stabilized, with the sand no longer encroaching (Salm pers. comm., 1985). A guard is employed to keep goats out and to control visitors to the area.

**Recommendations** Controls on goats and visitors must be sustained. It has been suggested that the island is uniquely well suited for biosphere reserve status (IUCN/UNEP, 1984). The proposed coastal zone management system for Mozambique includes the establishment of a pilot project at Inhaca (Forjaz, 1985).

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## PARQUE NACIONAL DO BAZARUTO

**Geographical Location** Includes the islands of Magaruque (Santa Isabel), Bangué and Benguerua (Santo Antonio) which lie between Ilha do Bazaruto and P. Santo Sebastião Peninsula, 10 km off the coast near Vilanculos; 22°00'S, 35°30'E.

**Area, Depth, Altitude** Park area is about 15 000 ha; altitude 0-50 m; includes islands and a 5 km zone around them.

**Physical Features** The islands of the Bazaruto Archipelago were once a peninsula but were isolated by the sea and/or wind action (Tinley, 1971). Vegetation is sparse (IUCN, 1987).

**Reef Structure and Corals** Coral formations are extensive (Tinley *et al.*, 1974).

**Noteworthy Fauna and Flora** There is a great abundance and diversity of marine molluscs, including tridacnid clams (Salm *in litt.*, 3.11.86). The Dugong *Dugong dugon* has been reported (Tinley *et al.*, 1974); Loggerhead *Caretta caretta* and Green *Chelonia mydas* Turtles nest on the nearby islands (Hughes, 1971a and b) and may therefore occur in the Park. Mangroves are described by Werger (1978) and there are extensive and diverse seagrass beds (Salm *in litt.*, 3.11.86). Brief details of the terrestrial fauna are given in IUCN (1987). The Nile Crocodile *Crocodylus niloticus* occurs on Bengerua Island (Tello, 1986).

**Scientific Importance and Research** A Zimbabwean organisation is planning a crocodile farming operation (Tello, 1986).

**Economic Value and Social Benefits** Paradise Island (Santa Carolina), lying to the south of the main group of islands, used to be one of the most popular tourist and recreational areas. Bangué is the only island without permanent inhabitants but fishermen from the mainland are frequent visitors. A private Zimbabwe tourist organisation is running fishing safaris in the area (Tello, 1986).

**Disturbance or Deficiencies** Preliminary work connected with possible oil related construction is occuring on the mainland and an offshore island nearby but damage to the Park has not been reported. In 1978 a large military base was being established on Ilha do Bazaruto (Werger, 1978). Turtle and dugong hunting still occurs (IUCN, 1987; Tello, 1986) and tourists are reported to take corals, shells and fish in large quantities and to spearfish (Tello, 1986).

**Legal Protection** Established as a National Park, May 1971 by Legislative Diploma 46/71.

**Management** Theoretically administered by the Ministry of Agriculture but no field staff have been appointed (IUCN, 1987).

**Recommendations** Ilha do Bazaruto has been proposed for incorporation in the park; it is already under a "special vigilance regime" with total exclusion of hunting. An antipoaching team and facilities for park staff are required, and apart from some limited and specialized tourism, most human activities should be prohibited (Tello, 1986).

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## PRIMEIRAS AND SEGUNDOS ISLANDS

**Geographical Location** 10-20 km off the mainland coast between Moma and Angoche (Antonio Enes); 16-17°S, 38-41°E.

**Area, Depth, Altitude** The islands are of varying altitude (Tinley, 1971).

**Physical Features** There are two strings of small islands: Primeiras, with five islands, to the south, and Segundos, with four, to the north. They lie on a shallow sandbar and are at varying stages of development, from completely bare to dense climax thicket cover; some are partly colonized by grasses while the larger ones have *Casuarina* trees. They are kidney-shaped, with the indentation on the leeside, opposite the open sea (Tinley, 1971).

**Reef Structure and Corals** The islands are encircled by fringing reefs, which are said to be in good condition although no studies have been made. A large part of the coral platform is exposed at low tide (Tinley, 1971).

**Noteworthy Fauna and Flora** The Primeiras Islands contain the most important Green Turtle *Chelonia mydas* nesting beaches in Mozambique, with about 200 females nesting annually (Groombridge, 1982; Hughes, 1971a), while the region between the islands and mainland is the most important in the Western Indian Ocean for Dugong *Dugong dugon* (UNEP, 1984). There are major seagrass beds between the islands (Tinley, 1971).

**Scientific Importance and Research** Salm (1983) states that these are some of the finest reefs of the country.

**Economic Value and Social Benefits** The islands are uninhabited and rarely visited by fishermen due to their distance from the mainland.

**Disturbance or Deficiencies** Not known.

**Legal Protection** None.

**Management** None.

**Recommendations** Recommended for designation as a protected area (Hughes, 1971a and b; Tinley, 1971; Tinley *et al.*, 1974).

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## QUIRIMBA ISLANDS

**Geographical Location** Centered at 12°30'S, 40°30'E.

**Physical Features** There is exceptionally clear water.

**Reef Structure and Corals** The islands are surrounded by fringing reefs.

**Noteworthy Fauna and Flora** The Hawksbill Turtle *Eretmochelys imbricata* is reported to nest here although this needs to be confirmed (Hughes, 1971a and b).

**Scientific Importance and Research** No information.

**Economic Value and Social Benefits** No information.

**Disturbance or Deficiencies** No information.

**Legal Protection** None.

**Management** None.

**Recommendations** Recommended for designation as a protected area (Tinley *et al.*, 1974).

# NORTH YEMEN

## INTRODUCTION

### General Description

North Yemen, or the Yemen Arab Republic, lying between 16°20'N and 12°45'N, has a coastline along the Red Sea of 450-765 km. This is low lying with sand dunes, wide beaches and spits of land running into the sea. The Zubayr (Zubair) Islands in the north (15°N) and the Hanish Islands in the south (13°30'-14°N) lie 30 and 20 miles (48 and 32 km) off shore respectively (Loulou, 1976). The coastal and marine biota of the country have been very little studied, although there is a small marine laboratory at Al Hudaydah (Hodeidah) and coastal surveys have been carried out (Loulou, 1976), most recently in the context of an IUCN project (IUCN, in prep.).

The climate is that of tropical deserts (Loulou, 1976) with oppressive heat (air temperatures range from 25 to 33°C on the northern coastal plain, the Tihama), low rainfall, totalling about 85 mm, which occurs on about 11 days each year (100-200 mm at Tihama, 74 mm at Kamaran), but high humidity. From October to March strong south-south-easterly winds predominate in the south, but winds moderate towards the north. There is virtually no run-off from land and no permanent rivers or springs, but there are occasional flash floods and temporary wadis. Flash flooding may be locally significant in determining marine substrate types, and freshwater seepage is also probably important. There is a diurnal tidal range of 0.5 m and a seasonal variation from 1.33 m in January to 1.03 m in July. Water salinity may be high in shallow areas with low circulation but in other areas it is lowered by groundwater seepage. Visibility is generally poor.

Seasonally inundated salt pans (sabakhats) or high energy sandy beaches dominate much of the coastline, the unconsolidated sediments principally arising from erosion of the Hyaz escarpment. Unlike further north in the Red Sea, raised reef rock features and other consolidated substrates are rare. The shallow sublittoral extends off shore for about 200 m, the sea floor descending to 50 m in terraces 4-8 m wide (IUCN, in prep.). Coastal sediments in the Al Hudaydah and Al Salif area and around Kamaran (under the jurisdiction of South Yemen; see section on Other Countries) are being studied by El Anbaawy (1984).

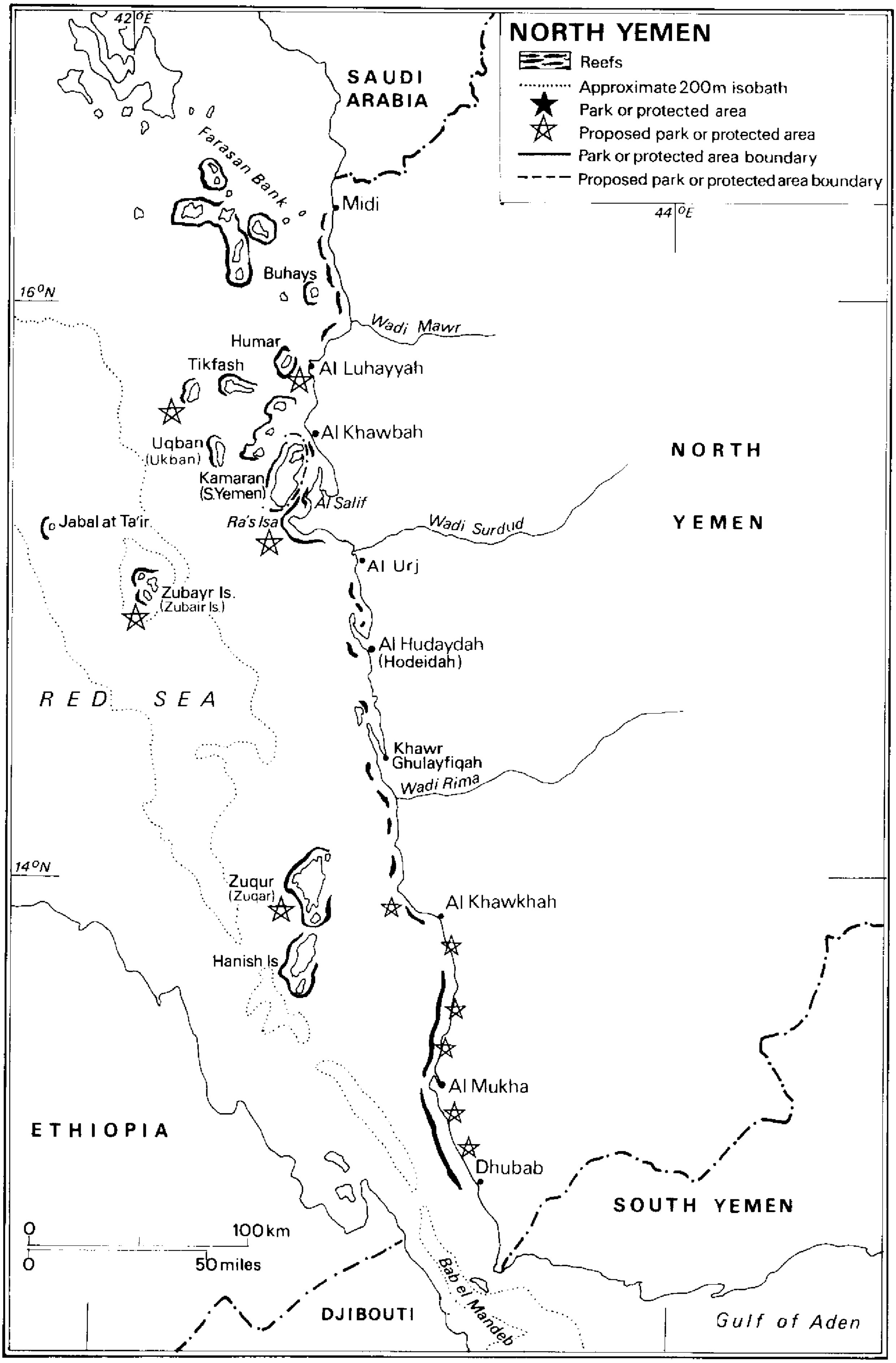
Fringing coral communities have developed on remnant fossil reef rock substrates in some areas, mainly immediately north of Al Mukha and between Al Mukha and Dhubab, but in general coral reefs are limited in extent owing to the rarity of hard substrate and the great depth of alluvial sediments on the shallow coastal shelf. These factors, combined with occasional flash floods, also cause high turbidity and sediment stress. Mangrove and seagrass areas are also limited in extent because of a relative paucity of sheltered locations and the strong seasonal winds, although towards the north there are more extensive sheltered habitats upwind of promontories and islands (IUCN, in prep.).

About 25% of the shore is fringed with shallow reefs or coral communities, mainly around Ra's Isa and Ra's Harafah near Al Salif and to the north and south of Al Mukha. The reefs generally have up to 12% coral cover, although some areas, for example to the north and south of Al Mukha, have higher coverage. Coral diversity is only moderate but many of the northerly reefs, such as those north of Al Hudaydah, support few hard corals and are dominated by *Sargassum* and calcareous algae. Most of the hard corals found are turbid water species. Hard substrates in the mainland area between Al Hudaydah and north of Al Khawkhah are rare, although occasional patches of profuse coral cover, such as one near Al Hudaydah and one in Khawr Ghulayfiqah, and reef rock patches may occur. Reef rock substrate and coral cover increase southwards from just north of Al Khawkhah, the *Sargassum* disappears and macroalgae is less abundant. In particular, from 5 km north of Al Mukha, south to just north of Dhubab, coral areas support profuse hard coral cover in depths extending from the intertidal (near Dhubab) or more generally from 1-2 m down to 5 m. Coral cover is dominated by foliose and branching types with occasional free-standing or encrusting massives. The south-west side of Ra's Isa, near Al Salif (15°16'N, 42°44'E), probably has the best developed coral reef on the Yemen mainland, and is reported to support profuse *Porites* growth.

The reef crest of the more northerly reefs consists only of sand shallows with little or no coral cover, and dense coral is found only at 2-3 m depth, rather than along a clearly defined reef edge and face. Further south, the sandy reef crest may be dominated by foliose or branching hard corals. Near Dhubab there is a relatively diverse reef flat, supporting dense stands of the alga *Caulerpa mexicana* and coral- and algal-encrusted reef rock with fungiids and occasional massive *Porites* colonies. Between Al Mukha and Dhubab there is an elongated patch reef, over 200 m wide, 2 m in depth, which may extend for several kilometres along the coast and has 100% *Galaxea* cover (IUCN, in prep.).

Fringing reefs are also found around the northern offshore islands, including those of the southern Farasan Bank, Uqban (Ukban), Jabal at Ta'ir, Zubayr, Zuqur (Zuqar) and Hanish. The Zuqur Islands (13°45'N, 42°45'E), just north of the Hanish Islands, are reported to have a rich sublittoral fauna, including corals. It is not known if there are any deep water ring reefs or pillar reefs similar to those found on the northern outer Farasan Bank in Saudi Arabia (IUCN, in prep; Loulou, 1976; Ormond, 1980). The offshore islands may well support more diverse coral growth than the mainland coast (as was the case on the Farasan Bank, compared to the adjacent Saudi coast) but they have not been surveyed yet (IUCN, in prep).

Mangroves are widespread on the mainland and on some islands, particularly north of Al Urj. Well developed mangrove is found along 84 km or 12% of the coast and less well developed mangrove along a further 38 km (5%) (IUCN, in prep.). The seagrass beds south of Al Khawkhah are important foraging areas for Green Turtles *Chelonia mydas* and possibly Hawksbills *Eretmochelys imbricata* (IUCN, in prep.). There may be some nesting on offshore islands, such as Kamaran (Groombridge, 1982), but no nesting has been



NORTH YEMEN
Reefs
Approximate 200m isobath
Park or protected area
Proposed park or protected area
Park or protected area boundary
Proposed park or protected area boundary
42°E
44°E
16°N
14°N
SAUDI ARABIA
Farasan Bank
Midi
Buhays
Wadi Mawr
Humar
Tikfash
Al Luhayyah
Al Khawbah
Uqban (Ukban)
Kamaran (S.Yemen)
Al Salif
Ra's Isa
Wadi Surdud
Jabal at Ta'ir
NORTH YEMEN
Al Urj
Zubayr Is. (Zubair Is.)
Al Hudaydah (Hodeidah)
RED SEA
Khawr Ghulayfiqah
Wadi Rima
Zuqur (Zuqar)
Al Khawkhah
Hanish Is
Al Mukha
ETHIOPIA
Dhubab
SOUTH YEMEN
0 100km
0 50 miles
DJIBOUTI
Bab el Mandeb
Gulf of Aden

recorded recently on the mainland (IUCN, in prep.). There are records of single Pacific Ridleys *Lepidochelys olivacea*. Further information is given in Walczak (1977). There are breeding populations of two species of Booby *Sula* spp., two species of Gull *Larus* spp., the Red-billed Tropicbird *Phaethon aethereus* and possibly the White-cheeked Tern *Sterna repressa* (Gallagher *et al.*, 1984).

**Reef Resources**

The coast is rich in fish and crustaceans of commercial importance including the lobster *Palinurus* and the swimming crab *Portunus pelagicus* and support an important artisanal fishery, although the commercial fishery depends mainly on pelagic species. Coral reef fish such as grouper (Serranidae) and snapper (Lutjanidae) are significant (7%) but are not a major element in the catch. Reef fisheries are important locally such as around Al Salif and Al Mukha. In 1980, fisheries made up 3% of the agricultural sector production. High seas limit fishing in winter and there is a seasonal migration of fishermen towards the more sheltered northern coast. Furthermore, the submarine terraces and reef structure create a sea floor which is too irregular for much trawling. Beach seining and handlining takes place along all coasts and sublittoral potting is carried out in sheltered waters. There are plans to develop the fishery industry and new fishery stations are being built (IUCN, in prep.).

Although a relatively poor country, with few motorized fishing craft, tourism is encouraged. The small islands in the north are reported to be good areas for diving (IUCN, in prep).

**Disturbances and Deficiencies**

No major impacts to the coastal and marine environment have yet been noted.

**Legislation and Management**

Law No. 20 of 1978 relates to fisheries and designates a permit/licensing system and bans the use of explosives or harmful substances (UNEP, 1980). Law No. 13 of 1976 relates to various aspects of marine pollution and identifies the protocol for forbidding discharge of oil, ballast, rubbish and other harmful substances into the marine environment. North Yemen is participating in the Programme for the Environment of the Red Sea and the Gulf of Aden and has signed the Regional Convention for the Conservation of the Red Sea and Gulf of Aden Environment. The focal point for regional marine conservation programmes is the University of Sanaa.

**Recommendations**

Plans for the development and regulation of the fisheries are being undertaken (Loulou, 1976) and this will assist in the establishment of Marine Parks and Reserves. Plans for marine conservation must take into account the fact that many areas have yet to be surveyed. The south-west side of Ra's Isa is considered a suitable site for a Marine Park, being convenient for tourists and for scientists from the marine laboratory at Al Hudaydah. A Marine National Park has also been suggested for the Zuqur Islands (Ormond, 1980), although survey work will be required first as this area is poorly known. A recent survey for IUCN has identified sixteen sites on the mainland coast deserving special management or protection. Several include coral communities, particularly sites at Al Luhayyah, Uqban, and six sites from Al Khawkhah to Dhubab. The Zubayr Islands also require special management (IUCN, in prep.).

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# PHILIPPINES

## INTRODUCTION

### General Description

The Philippine Archipelago of more than 7000 islands lies in the tropical Indo-West Pacific approximately 4°40'-21°50'N, 116°50'-136°35'E. With the exception of embayments and large deltaic areas, virtually the whole coastline of the country is dotted with coral reefs or coral communities.

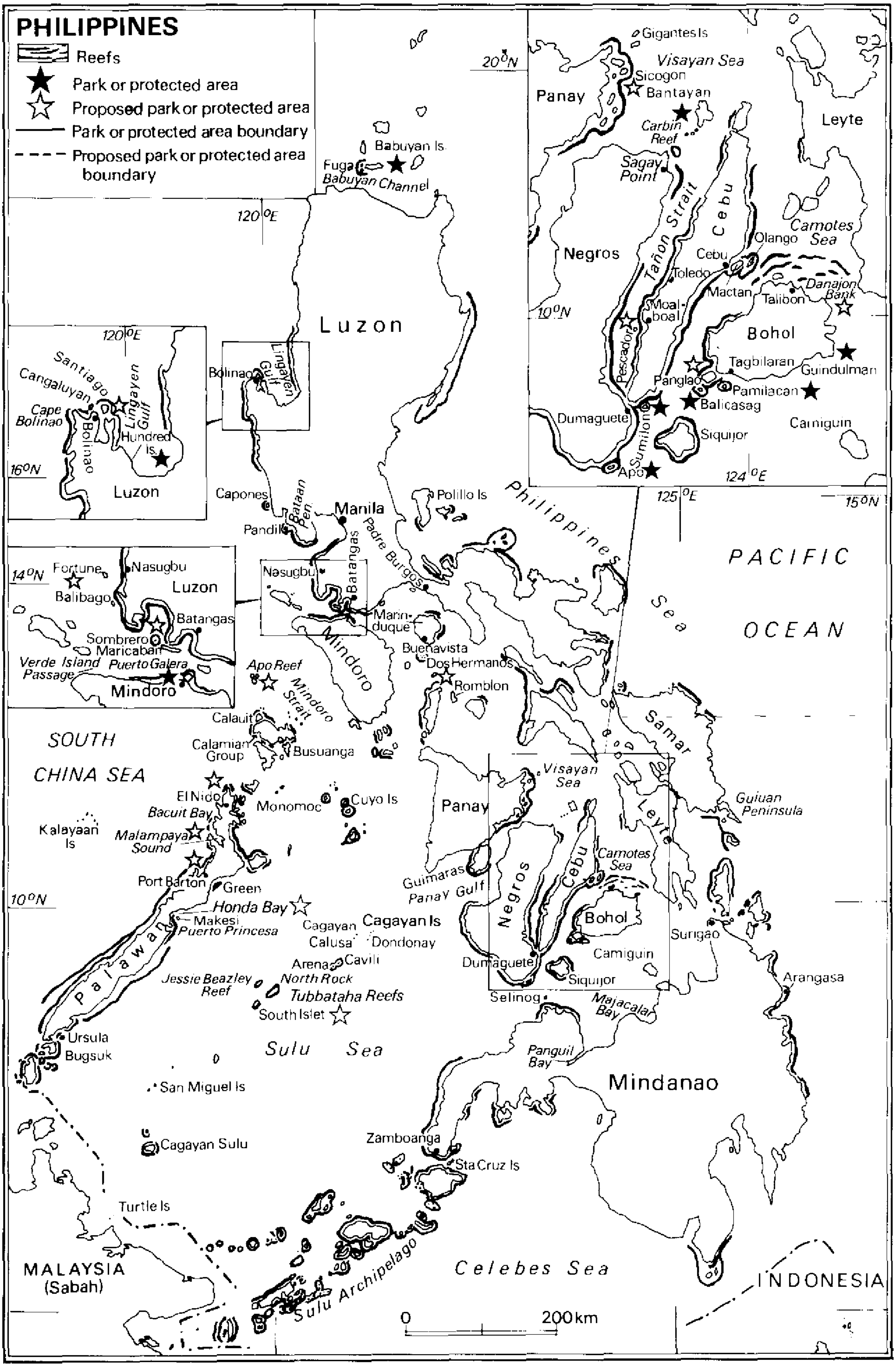
Philippine reef areas have been estimated to be about 27 000 sq. km in extent, with the largest concentration in the south-west of the country. The eastern seaboard facing the open Pacific Ocean, with the major exceptions of south-east Luzon and the southern Samar shelf, is characterized by steep slopes with no major reef areas. In contrast, the inland seas and the western seaboard, especially off Palawan, are lined with fringing reefs and numerous banks and shoals of coralline origin. Detailed accounts of reef distribution are given in UPMSC (1979, 1980 and 1982) and White (1984).

Around the largest island, Luzon, coral reefs are concentrated in the central western section from Bolinao, Pangasinan, down to Batangas Province. Reefs around Fortune Island, Sombrero Island, in the Hundred Islands National Park and off Bolinao are described in separate accounts. Gomez (1977) describes a poorly-developed reef around Pandil Island, on the east coast of the Bataan Peninsula, north of Manila. The small fringing reefs around the volcanic Capones Island slightly further north were briefly investigated by Pichon (1977b). Reefs and coral communities also abound on the Polillo Island shelf off the east coast of Luzon. The Babuyan Island group at the extreme north is characterized by narrow disconnected fringing coral reefs, as at Fuga Island (*see separate account*). South-west of Luzon, reefs are found around Mindoro (*see account for* Puerto Galera) and Romblon (*see account for* Dos Hermanas). Ang (1985) describes *Sargassum* on the reef flat at Balibago, Calatagan (13°56'N, 120°37'E). Reefs around Cangaluyan Island are described by Banzon *et al.* (n.d.) and Aliño *et al.* (1985).

The larger islands in the Visayas (Central Philippines) all possess significant coralline areas, although many of these are separated by wide expanses of soft sediments, especially where there are extensive continental shelves and large river mouths. Reefs in the vicinity of Sumilon (Cebu), Mactan and adjacent islands (Cebu), Pescador Islands (Cebu), Sicogon (Panay), Carbin Reef (Negros), Danajon Bank, and Panglao and Balicasag Islands (off Bohol) are described in separate accounts. Reefs on the east coast of Cebu and southern Negros, in the Tañon Strait area, have been studied in relation to pollution by Corpuz and Aliño (1983), Laudencia *et al.* (1973) and Lowrie *et al.* (1982). Reef-associated zooplankton from Padre Burgos, Quezon (13°53'N, 121°47'), have been studied by Walter *et al.* (1981). White (1984 and 1986b) describes the rather poor reef community off Bantayen Beach, just north of Dumaguete. Reefs around the Gigantes Islands, to the north-east of Panay, were briefly investigated by Pichon (1977b); they vary from coral communities without reef construction to small fringing reefs. The reef around Pamilacan Island, south of Bohol, is decribed by Savina and White (1986a and b). Alcala and Gomez (1985) briefly describe reefs at Selinog (an island of 90 ha in the Mindanao Sea which has a reef of 126 ha with 29% coral cover and a drop-off) and Hulao-Hulao (a barrier reef of 50 ha in Panay Gulf, 250 m from the Negros mainland, also briefly discussed by Alcala and Luchavez (1984)). Reefs around Mindanao are less well known although those around Arangasa islet off the east coast of Surigao del Sur Province have a rich scleractinian fauna, 123 species having been identified (Nemenzo and Montecillo, 1981).

There is a dearth of information on the reefs in this portion of the South China Sea, such as the atoll-like Scarborough reefs west of Luzon. The banks and shoals west of Palawan are marked "Dangerous Grounds" on nautical charts because of the mainly uncharted coralline areas. Extensive geological studies have been made by oil companies but data are at present unavailable (Hodgson *in litt.*, 9.2.87); further work is needed to resolve the question of whether the banks constitute a barrier reef, which could be one of the largest in the world. The reefs around the Kalayaan Islands were surveyed by BFAR in 1980 for the Philippine Navy, to check on erosion on Pagasa (Thito), the largest island in the group (Castañeda, 1981a). Palawan and its satellite islands have some of the best reefs in the country. A general description of the island is given in Bruce (1981) which mentions several reef areas; additional data is available in UPMSC (1979) and Hunting Technical Services (1985). White (1984 and 1986b) describes reefs around Calauit (Calawit) Island and Maltanubong Islands off the northern tip, both of which have good quality fringing reefs. The reefs of Bacuit Bay, El Nido, in the north-west, and Honda Bay, on the east coast, are described in separate accounts. Green Island, north of Honda Bay, was briefly investigated by Pichon (1977b) and is popular with divers (Bruce, 1981). Ursula Island, lying 30 km off the south-east coast, has good quality fringing reefs (Bruce, 1981). Trono and Ang (1982) describe marine benthic algae from Bugsuk Island, off the southern tip.

The deep Sulu Sea to the east is rimmed by reefs and divided into two basins by the submarine Cagayan Ridge that includes two atoll systems, Cagayancillo (Cagayan Islands) on the north-east and Tubbataha in the centre (*see separate accounts*). Apo Reef (*see separate account*), an atoll-like formation, is located to the north of the Palawan arc system towards the island of Mindoro. In contrast to the volcanic and igneous basements of most atolls, it is situated on an old land mass, a part of the Asiatic continental shelf. The southern part of the Sulu Sea is bounded by Sabah, Malaysia, to the south-west where the Turtle Islands are found and by the Sulu Archipelago with its fringing reefs and atolls to the south-east. These also have some of the best Philippine reefs and are briefly described by Romero and Zacher (1981). The majority of Philippine reefs are fringing reefs. Atolls and the possible barrier reef west of Palawan were mentioned above. The double-barrier in the Danajon Bank off Bohol is described in a separate account, and there may be a further few small barrier reefs.


PHILIPPINES
Reefs
Park or protected area
Proposed park or protected area
Park or protected area boundary
Proposed park or protected area boundary
Luzon
Babuyan Is
Fuga
Babuyan Channel
Lingayen Gulf
Bolinao
Santiago
Cangaluyan
Cape Bolinao
Hundred Is
Capones
Bataan Pen
Manila
Pandil
Padre Burgos
Polillo Is
Philippines Sea
PACIFIC OCEAN
Nasugbu
Fortune
Balibago
Batangas
Sombrero
Maricaban
Verde Island Passage
Puerto Galera
Mindoro
Marinduque
Buenavista
Dos Hermanos
Romblon
Apo Reef
Mindoro Strait
Calauit
Calamian Group
Busuanga
SOUTH CHINA SEA
El Nido
Bacuit Bay
Monomoc
Cuyo Is
Kalayaan Is
Malampaya Sound
Port Barton
Green
Honda Bay
Makesi
Puerto Princesa
Cagayan Calusa
Cagayan Is
Dondonay
Arena
Cavili
Jessie Beazley Reef
North Rock
Tubbataha Reefs
South Islet
Palawan
Ursula
Bugsuk
Sulu Sea
San Miguel Is
Cagayan Sulu
Turtle Is
MALAYSIA (Sabah)
Sulu Archipelago
Zamboanga
Sta Cruz Is
Celebes Sea
INDONESIA
Mindanao
Panguil Bay
Majacalar Bay
Selinog
Panay
Guimaras
Panay Gulf
Negros
Cebu
Bohol
Dumaguete
Siquijor
Camiguin
Visayan Sea
Camotes Sea
Leyte
Samar
Guiuan Peninsula
Surigao
Arangasa
Gigantes Is
Sicogon
Bantayan
Carbin Reef
Sagay Point
Tañon Strait
Olango
Mactan
Toledo
Moal-boal
Pescador
Talibon
Danajon Bank
Tagbilaran
Guindulman
Panglao
Pamilacan
Balicasag
Sumilon
Apo
0
200 km
120°E
20°N
16°N
14°N
10°N
124°E
125°E
15°N

At present, some 90 coral genera are known from the Philippines (Gomez, in press) and a review of the coral fauna is in preparation (Veron and Hodgson, in prep.). Other taxonomic studies include the early work of Faustino (1927), a series of comprehensive publications by Nemenzo (1955-1975), and Hodgson and Ross (1981), Nemenzo (1983), Nemenzo and Hodgson (1983), Nemenzo and Montecillo (1981) and Pichon (1977b). There are reference collections at the Universities of the Philippines and of San Carlos and taxonomic work is summarized by Nemenzo (1981). A UNEP coral taxonomy workshop was held at the Bolinao Marine Laboratory of the University of the Philippines Marine Sciences Institute in 1986. There are numerous publications on reef-associated fauna such as turtles, fish, seabirds and invertebrates but this information has not been collated at the time of going to press. Early reviews and bibliographic works include Dickerson (1928) and Nemenzo (1969). The status of Giant Clams in the Philippines is described in Alcala (in press).

The reefs have attracted the attention of various researchers in the past century and the earlier part of the twentieth century, but it has only been in the past decade that a significant national effort has emerged to assess and manage these ecosystems. Darwin (1851) gave a brief account of Philippine coral reefs and Faustino (1927 and 1931) presented more complete reports on the corals of the archipelago. Alcala *et al.* (1987) synthesize current knowledge on Philippine reefs.

Reef-related research programmes are underway through the Marine Sciences Institute of the University of the Philippines, Silliman University (Dumaguete), the University of San Carlos (Cebu), all of which have marine laboratories, and the Bureau of Fisheries and Aquatic Resources (BFAR) and the Natural Resources Management Center (NRMC). Coral growth studies of around 33 genera have been made (Gomez *et al.*, 1985). Coral reef survey methods used in the Philippines are described in Gomez and Alcala (1984) and remote sensing methods have been initiated by NRMC. Preliminary transplantation experiments have been undertaken and coral recolonization and recovery in some areas have been monitored (Alcala *et al.*, 1982; Auberson, 1982; *see accounts for* Bolinao reefs and Sumilon). Studies are now underway to link the productivity of coral reefs to fish populations (*see below*). In 1978 and 1979 the Smithsonian Institution carried out surveys of marine organisms in the Central Visayas in collaboration with a number of the institutions mentioned above. Results of studies on marine algae are given in Meñez and Calumpong (1981). The Univeristy of Kiel, West Germany, carried out an interdisciplinary study of the reefs in the area between Mactan and Olango in 1980/81 in co-operation with the University of San Carlos (Wefer, 1985).

**Reef Resources**

The importance of coral reefs to the economy of the Philippines cannot be overemphasized. Owing to the large number of coastal settlements, millions of Filipinos depend on reef ecosystems for their livelihood. It has been estimated that coral reef fish account for 8-15% of the total catch of finfish per year (Carpenter, 1977; Murdy and Ferraris, 1980). As reef gleaners collect seaweeds and various invertebrates in addition to fish, the dependence of some communities on coral reefs may be considerably greater. Fish yields have been determined for several reefs and vary from 5.2 tons/sq. km/year (Hulao-Hulao, Panay) to 37 tons/sq. km/year (Sumilon, Bohol Strait) (Alcala and Gomez, 1985). A general review of Philippine fisheries is given in Smith *et al.* (1980) and more detailed studies of reef fishery yields have been carried out at Sumilon, Apo Island and Balicasag (*see separate accounts*) and Pamilacan (Savina and White, 1986b). The aquarium fish trade is substantial, over 1.9 million reef fish having been exported to the USA in 1982 alone (Albaladejo and Corpuz, 1981; Anon, 1987). Traditional fisheries and their implication in modern management is discussed by Lopez (1985).

Numerous cottage industries have been established to produce shellcraft and there is a large trade in ornamental shells, many of which are from reefs (Wells, 1981, 1982b and c). Cebu and Zamboanga are the two main centres, although many firms also operate out of Manila. Although the gathering of stony coral was illegal from the late 1970s until 1986, it was, and still is, collected in large quantities for construction purposes and the ornamental coral trade, the Philippines being the main exporter in the world (Alcera, 1981; McManus, 1980; Wells, 1981; Ross, 1984).

Reefs play an important role in the fast-developing tourist industry and increasing numbers of divers, both local and foreign, are visiting them. Dive tours are arranged out of the major cities and increasing numbers of specialist dive resorts are being established on offshore islands (*see following accounts*). Bruce (1981) and Hunting Technical Services (n.d.) discuss the development of tourism on Palawan.

**Disturbances and Deficiencies**

The Philippines, being situated in the typhoon belt, experiences extensive damage on some reef areas, such as those around Mactan (*see separate account*), brought about by these catastrophic events. Aggregates of the gastropod *Drupella rugosa* caused some coral damage at Mactan Island in the early 1980s (Moyer *et al.*, 1982). *Acanthaster planci* may have contributed to damage in some areas (Alcala, 1976; *see accounts for* Apo Island and Cagayan Islands), Alcoy (Cebu) (Aliño *et al.*, 1981) and Bantayan Island (Cebu) (UPMSC, 1982).

The status of Philippine coral reefs was assessed by the Marine Sciences Center of the University of the Philippines, with the assistance of other collaborating institutions, over a period of more than half a decade for the Ministry of Natural Resources (Gomez and Alcala, 1979; Gomez *et al.*, 1981; UPMSC, 1979, 1980 and 1982). Less than one-third of the Philippine reefs surveyed were in excellent or good condition. While nearly 40% were in fair condition, nearly one-third were in a poor state and less than 5% had excellent coral cover. For a broader treatment of degradation of reefs in the Philippines and South-east Asia, see Gomez (1980) and Yap and Gomez (1985); general descriptions of the variety of problems affecting the reefs are given in Gomez (1979), Wells (1982b) and White and Wells (1982).

Collection of coral for the ornamental coral trade has been a major issue, causing at least localised damage to reefs, particularly in Cebu (McManus, 1980; Ross, 1984; Wells, 1981 and 1982b). Coastal erosion around Cebu is also considered to be due to removal of coral for tile-making. On Pagasa Islands, in the Kalayaan group, off Palawan, the mining of corals for use in a runway extension has also led to erosion (Castañeda, 1981a). In Bicol, where coral has been used for road construction, coastal erosion has also been evident (Rogacion, 1985). The collection of shells has also had a localised impact (Wells, 1982b and c). Giant Clams *Tridacna* spp. have been particularly seriously affected, since they are collected for both their shells and meat, the latter largely by Taiwanese fisherman. *T. gigas* and *T. derasa* are now considered extinct in the Philippines (Alcala, in press).

Dynamite fishing has caused extensive damage to reef throughout the Philippines. Many sites described in the following accounts have been affected in this way; other sites include Pandil Island, north of Manila (Gomez, 1977), Selinog Island in the Mindoro Sea and Hulao-Hulao reef in the Panay Gulf (Alcala and Gomez, 1985) and Cangaluyan Island (Aliño *et al.*, 1985). Alcala and Gomez (1979) studied recolonization of reefs which had been blasted in southern Negros, Cebu, Sumilon, Apo, Siquijor, Guimaras and the northern part of Mindanao. Muro-ami fishing has also caused damage, for example in the Dumaguete region (Anon., 1985b) and may result in serious overfishing. Descriptions of the method are given by Anon. (1985b) and Hall (1985) and its impact and that of kayakas fishing is described by Carpenter and Alcala (1977). The use of cyanide and other poisons to collect fish for the aquarium fish trade has also caused problems on some reefs (Anon., 1987).

The effect of tailings discharged from copper mines and siltation on reefs has been studied in the vicinity of Toledo City, on the east coast of Cebu, and in southern Negros (Lowrie *et al.*, 1982; Laudencia *et al.*, 1973; Corpuz and Aliño, 1983). Mining has caused the rivers of Cebu and Negros to be heavily silt-laden which has had a significant impact on reef communities (Butler *in litt.*, 1.85). Alcala (1977a) discusses the impact of pollution on reefs around Negros and Aliño *et al.* (1981) describe marine communities adjacent to the Philippine Mining Services Corporation Pier at Alcoy, Cebu. Hudson *et al.* (1982) describe the impact of offshore oil drilling on reef corals. This could eventually have an impact in the Palawan area where there has been extensive offshore prospecting, and two wells are now in operation off El Nido (Hodgson *in litt.*, 9.2.87). A preliminary study on the effects of an oil well at El Nido in Palawan indicated that there was some impact on the marine communities, although the results were inconclusive (UNEP, in prep.). The impact of sedimentation on reefs is serious and extensive, particularly on fringing reefs around the larger islands where deforestation has taken place on a massive scale (Alcala, 1977b; Rogacion, 1985; Yap and Gomez, 1985). In northern Palawan, for example, a recent study has found that sedimentation has been highly destructive in localized areas (Hodgson *in litt.*, 9.2.87).

**Legislation and Management**

A large number of government institutions are directly or indirectly involved with coastal zone research and management but none has responsibility for management as a whole. The National Environmental Protection Council (NEPC) is the central authority charged with environmental protection. In 1977 it initiated a Coastal Zone Management Programme, and a Marine Parks/Reserves Development (MPRD) Inter-Agency Task Force of 22 agencies was established. This has carried out a variety of assessments and studies including an inventory of coastal zone resources (UPMSC, 1979, 1980 and 1982); the MPRD Programme is described by Palaganas and Biña (1981). A Master Plan for coastal zone management was formulated and its implementation is now being worked on, including the preparation of recommendations for improved legislation and enforcement (Tolentino, 1984; Palaganas, 1985). Under P.D. 1698, jurisdiction of all coral reef resources was given to BFAR (Bureau of Fisheries and Aquatic Resources) which initiated a management scheme (Castañeda, 1981b and 1984) aimed at creating a variety of forms of protected area.

There are numerous confusing and overlapping pieces of legislation concerning the establishment of marine protected areas. However, as yet no national marine park, in the internationally accepted meaning of the term, has been set up. Areas often referred to as marine parks are in fact national parks, game refuge and bird sanctuaries, seashore parks, fish sanctuaries, "tourist zones and marine reserves" or other (MPRDP, 1986; NRMC, 1983; White, 1979). The main reef areas mentioned under such legislation are listed below, as well as areas where efforts are now underway to set up internationally recognisable marine protected areas.

1. A number of National Parks and reserves have been created by Presidential Decree and are under the jurisdiction of the Bureau of Forest Development (BFD), but the Parks and Wildlife Division of the BFD is technically only responsible for terrestrial areas.

- Hundred Islands National Park, 1940 (Pangasinan, Luzon) (*see separate account*).
- Manila Bay Beach Resort, established in 1954 under the jurisdiction of the BFD but has never been implemented. The minimal coral reef areas and coral communities which once occurred have been eliminated by pollution and other disturbances due to the proximity of the port of Manila and the development of the coastline (Castañeda *in litt.* to Salvat, 28.3.80; White, 1981); the area is no longer considered suitable for development as a protected area.
- Puerto Galera Biosphere Reserve (Mindoro) (*see separate account*).
- Santa Cruz Islands National Park (for Tourism Development) (Zamboanga); declared by Presidential Decree No. 654, 1975, under the jurisdiction of BFD (Gomez *in litt.* to Salvat, 16.4.79; Trono, 1977); fringing reefs; visited by tourists until political situation affected tourist industry; there is no management.
- Sumilon Island Marine Reserve and Fish Sanctuary (Cebu) (*see separate account*).
- Fuga Island Underwater Museum (*see separate account*).

2. A Presidential Decree of 14.4.70 declared a number of marine sanctuaries and biological stations as protected

areas, the latter being mainly used for collecting specimens (White, 1981):

- Camiguin Island; northern Mindanao; no management; also a Tourist Zone/Marine Reserve (*see below*).
- Guiuan Peninsula; southern end of Samar island; good coral reefs but no management (Castañeda *in litt.* to Salvat, 28.3.80); also a Tourist Zone/Marine Reserve (*see below*).
- Malampaya Sound; northern Palawan; no management under the decree but Fisheries Administrative Order No. 154 of 26.4.86 established a closed season for five years for the operation of any fishing gear in the area except for that specified in the Order (Gomez *in litt.*, 12.2.87).
- Nasugbu; Batangas, Luzon; minimal coral reefs; no management; also a Tourist Zone/Marine Reserve (*see below*).
- Panguil Bay; northern Mindanao; minimal coral reef; no management, although previously a proposed site for marine park development.
- Polillo Islands; eastern Quezon Province; some good coral reef areas; the Parks and Wildlife Office has a bird sanctuary on the coral islet, Minasawa, also not managed (Castañeda *in litt.* to Salvat, 28.3.80) although legal protection is provided by the Fisheries Administrative Order No.7, 1964 (Gomez *in litt.*, 12.2.87).
- Turtle Island; opposite north-east point of Sabah, Sulu Sea; good coral areas and major rookery for the Green Turtle *Chelonia mydas* which receives some management; the Sabah section is already managed as a reserve (*see chapter on* Malaysia) (Castañeda *in litt.* to Salvat, 28.3.80)
- Of the Marine Biological Stations, only Macajalar Bay Marine Biological Station, northern Mindanao, and Puerto Galera (*see separate account*) are adjacent to coral reefs.

3. Presidential Proclamation 1801 of 1978 declared a large number of sites over a vast area (one municipality, ten provinces and 65 islands and parks) as tourist zones and marine reserves under the administration and control of the Philippine Tourism Authority (Palaganas and Biña, 1981). PTA Circular No. 10 of 2.9.79 gives general regulations governing activities in these areas. Regulations of 11.12.80 control the activities of SCUBA divers and diving operators and prohibit spearfishing with SCUBA within two nautical miles of the tourist zones. However, these areas have never been properly established and the regulations have never been enforced, although the latter have occasionally been cited to provide support for the enforcement of areas declared as protected under separate legislation. Some of these areas were mentioned above; the most important in terms of coral reef management are described in separate accounts and listed below:

- Apo Island (Negros)
- Apo Reef (Mindoro)
- Fortune Island (Batangas, Luzon)
- Fuga Island Underwater Museum (Babuyan Islands, Luzon)
- Honda Bay (Palawan)
- Mactan, Olango, Lassuan, Coahagon and Panganan (Cebu/Bohol)
- Panglao/Balicasag Island (Bohol)
- Sombrero Island (Batangas, Luzon)
- Santa Cruz Islands (*see above*)

Selinog Island, between the southern tips of Cebu and Negros is also a Tourist Zone/Marine Reserve and is briefly described in (Alcala and Gomez, 1985).

4. Palawan, as the least disturbed island in the Philippines, has been designated a Game and Bird Sanctuary and, under Presidential Proclamation No. 2152, a Mangrove Swamp Forest Reserve. All small offshore islands have been declared National Reserves under Presidential Proclamation 219 (amended by Proclamation No. 530-13) or have been designated as other forms of protected area. These include Ursula Bird Sanctuary (Bruce, 1981; IUCN, in prep.), Caluit Island Game Reserve and Maltanubong Island, which has a protected sea turtle nesting beach (White, 1984) and the Cagayan Islands (*see separate account*). Much of the main island and most of the small offshore islands are surrounded by reefs but these are not protected, although they receive some degree of protection, as on Calauit Island, by virtue of the presence of Park staff (White, 1986b).

5. More recently there has been a move to establish municipal marine parks, under municipal order and managed by local people (Castañeda and Miclat, 1981). BFAR extension workers help to initiate the reserves by setting up education programs and holding slide shows and discussions Reserves have been established at:

- Carbin Reef (Sagay), Negros (*see separate account*)
- Guindulman: initiated in 1978, this is located in Barangay Basdio within municipal waters and covers 50-60 ha along a 5 km stretch of the south coast of Bohol, near Katahoman. Following a survey of the reefs by BFAR, the park was created under Municipal Order No. 12, 1982. All destructive activities were prohibited, but the current status of the area is not known. Coral reef biology and ecology seminars have been conducted by BFAR and the Environmental Center of the Philippines (ECP) (Castañeda and Miclat, 1981; Gomez *in litt.*, 12.2.87; White, 1981).
- Tagbilaran: an artificial reef was constructed from tyres and, in 1980 recommendations were made to prevent destructive fishing methods, coral extraction, and pollution from sewage and boat discharges (White, 1981); the current status of this area is not known.

A Marine Conservation and Development Program, initiated in 1974 at Silliman University, is working to the same ends (Savina and White, 1986a; White and Law, 1986; White *et al.*, 1986; White and Savina, in press b). This involves the establishment of marine reserves around the entire perimeter of an island up to a distance of 500 m from shore. Within this, the use of dynamite, poisons, very small gill nets and the techniques of spearfishing and muro-ami are prohibited. The reserves are established with municipal legal support and are managed by island-resident Marine Management Committees. Within each reserve, a fish sanctuary, marked with buoys and signs, is established where fishing and collecting of marine organisms is prohibited, large motorized boats may only anchor to anchor buoys and breeding stocks of Giant Clams are protected. Community education centres established on each island provide meeting places for the committees and other groups and education is given a high priority. Recent surveys have shown an increase in fish diversity and abundance within each reserve. Small agro-forestry and improved farming projects have been started on Apo and Pamilacan as alternative sources of income from fishing (White, 1986a; White *et al.*, 1986). Such reserves have been established at:

- Apo Island (*see separate account*).
- Panglao/Balicasag (*see separate accounts*).
- Pamilacan: a low coralline island, less than 200 ha in area with a reef of 180 ha in area; low coral cover due to destructive fishing practices; reserve established under Ordinance No.8. 1985, Municipality of Baclayon, with fish sanctuary of 14 ha along 550 m of western shore off Mangga Beach (Savina and White, 1986b; White and Law, 1986; White and Savina, in press b). Ordinance No.3 of 13.2.86 assigns management of the area to the Marine Resource Management Committee and island residents, in conjunction with the Sangguniang Bayan of Baclayon, Bohol (Gomez *in litt.*, 12.2.87).

Local efforts to establish protected areas at Sicogon, Moalboal/Pescador Islands and El Nido, Bacuit Bay, are described in separate accounts. These involve either the municipal council or private diving resorts; the resort at El Nido has been particularly active in stimulating enforcement of fisheries legislation and provides a model that could be followed elsewhere (Hodgson *in litt.*, 9.2.87). Local efforts at reef management are also underway in the Monomoc Islands of the Cuyo Group, to the east of Palawan, under a project sponsored by U.S. AID and the A.S. Soriano Foundation (Ross pers.comm., 1987).

Enforcement of legislation to protect and manage marine resources is very poorly implemented, although there are a number of appropriate decrees and legislation. Destructive fishing methods, particularly dynamite fishing, are prohibited; muro-ami fishing was declared illegal in 1986 (Hodgson *in litt.*, 9.2.87). The gathering or harvesting of stony corals was banned under Presidential Decrees 1219 and 1698 of 1977 and 1980 but in May 1986 these bans were lifted for one year, permitting export of existing stocks. A Presidential Decree of 1980 bans the collection of turtles or their eggs and the export of turtle products (White, 1981).

A number of Unesco workshops and training courses have been held at the University of San Carlos, Cebu, including one on "Shallow Water Ecosystems" in 1981, held in the course of the project undertaken by the University of Kiel in the Mactan area (Schramm *et al.*, 1981; Wefer, 1985).

**Recommendations**

The BFAR coral management scheme aims for the establishment of three types of protected areas: resource reserves for remote, unsurveyed areas (examples include the Kalayaan Islands and Sulu Sea); national marine parks of 500 ha or more with government legislation; and municipal coral reef parks of 50-500 ha within the municipality (Castañeda, 1981b and 1984). A list of marine park proposals is also given in MPRPD (1983). Many of the existing declared areas need improved management or actual implementation. The following areas have been proposed for some form of protection:

- Apo Reef proposed Marine Park
- Sombrero Island
- Fortune Island
- Tubbataha proposed marine reserve
- Sicogon proposed Municipal Park
- Moalboal/Pescador Island proposed Municipal Park
- Santiago/Silaqui Island fringing reef (Pangasinan, Luzon)
- Danajon Bank (Bohol)
- Dos Hermanas (Romblon, Marinduque)
- Palawan: a Strategic Environmental Plan has been produced for the whole area with the aim of stimulating economic development whilst safeguarding its natural resources (Hunting Technical Services, n.d.). It is concerned predominantly with terrestrial resources but includes recommendations for the marine environment:
    - Honda Bay Marine Park (*see separate account*).
    - El Nido Marine Park, Bacuit Bay (*see separate account*).
    - Port Barton Marine Park; San Vicente, Pagdanan Bay; reefs have already suffered damage from dynamite, muro-ami fishing, tourists and siltation (Hunting Technical Services, 1985).
    - Malampaya Sound (*see above*); Sanctuary declared in 1970 but never implemented.

Castañeda (1981a) recommends improved management of the reefs in the Kalayaan Islands off Palawan.

The creation of marine parks at Honda Bay, Tubbataha Reef and San Miguel Islands, and Apo Reef is considered an urgent priority under the Corbett Action Plan for Protected Areas of the Indomalayan Realm (Thorsell, 1985).

Under the coral reef resources management scheme of BFAR, the fisheries licensing system is to be revised in order to regulate and control take of reef products while generating income. Communal reef fishing grounds would be managed by local people on a tenure system to alleviate problems in fishing communities in the Sulu Sea and Palawan where reefs are exploited by migrant fishermen from the Central Visayas. Other components of the programme include the introduction of local marketing cooperatives, education, with a nationwide reef conservation extension program, and further research (Castañeda, 1984). Monitoring programmes are underway on degraded reefs (NRMC, 1984a). Artificial reef programmes are being developed at Caubian Island in the Central Visayas under the BFAR Coral Reef Project, and with U.S.AID, at a second site in the Central Visayas (Hodgson *in litt.*, 9.2.87). Early recommendations for reef management were given in Fisheries Research Division (1981) and fisheries management was described in Juliano (1979). A new programme is being developed to improve management of the aquarium fish trade and phase out poisoning of reef fish. This will involve the training of collectors, new regulations and educational and publicity efforts, co-ordinated by the International Marinelife Alliance (Anon., 1987).

Recommendations for improved management of the coral and shell trades are given in Ross (1984), Grigg (1984) and Wells (1981 and 1982c). Giant Clams are being farmed at Silliman University with the aim of supplying fishermen with juveniles for restocking (Alcala, 1985). A National Conservation Strategy for the Philippines is being developed which will take the conservation requirements of reefs into consideration (Haribon Society, 1983).

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## APO ISLAND MUNICIPAL RESERVE

**Geographical Location** Some 6 km off the south-eastern coast of Negros Island, Central Philippines, approximately 25 km south of Dumaguete City, and west of Siquijor Island; 9°05'N, 123°16'E.

**Area, Depth, Altitude** 74 ha; 150 m at highest point; area of fringing reef to the 60 m isobath is about 106 ha.

**Land Tenure** Government and private.

**Physical Features** Apo Island is a small volcanic island with a steep, rocky coastline, five white sand beaches and a fringing reef. The principal beaches are located on the south-east and south-west. Except in some steep, rocky areas, little original vegetation remains. The island has a small, shallow (4.5 m deep) lagoon on the south-west side overgrown with mangroves. A lighthouse is located to the north (White, 1984).

North-east and south-west monsoons affect wave action around the island. Currents are consistent throughout the year but vary daily with tidal changes. The strongest current is from the north and north-east and passes south along the east and west of the island (White, 1984). Visibility is excellent, usually more than 100 feet (30 m) (Smith *et al.*, 1982).

**Reef Structure and Corals** The reef morphology is of the standard fringing reef type with an average width from shore to reef crest of 100 m around the island. Beyond the reef crest, slopes are generally greater than 30° (Cabanban and White, 1981).

The east and south-east portions of the reef have the most extensive live coral cover. Volcanic rock boulders provide substrate for much coral growth and permit a topographically diverse reef atypical of most Philippine island reefs, which are strictly coralline. Total living coral cover in the area was estimated to be 70% in 1977 (UPMSC, 1982). A 1983 survey showed good coral cover of about 63%, equally divided between hard and soft corals (White, 1984). The abundance of soft corals may reflect the rocky substrate, but may also be a result of the fact that soft corals may grow better than hard corals in disturbed areas. Coral rubble was found to be insignificant and there was little dead standing coral, except in the south-east, where *Acanthaster* has decimated large colonies of branching coral. The topographic index was high, as massive coral is the dominant hard coral growth form (White, 1984).

A total of 48 hard coral genera has been reported around Apo Island. *Galaxea* sp. is dominant, followed by *Acropora* sp. and *Porites* sp. (White *et al.*, 1984).

**Noteworthy Fauna and Flora** Reef fish include mainly acanthurids, scarids, caesiodids, plectorhynchids, epinephelids, and lutjanids. Pelagic species include carangids, elopids (tenpounders), scomberomids, and sphyraenids (Alcala and Luchavez, 1981). Larger fish in the area include jacks of many different species and Black-tip and White-tip sharks (Smith *et al.*, 1982). Invertebrates such as octopi, gastropods, sea cucumbers, shrimps, and algae (*Gracilaria* sp. and *Caulerpa* sp.) are found on the reef (Alcala and Luchavez, 1981). Sea turtles are rarely found.

**Scientific Importance and Research** The Apo Island reef is frequently used for research because of its relatively good condition. The impact of human activities on the reef has been studied (Russ, 1984) and the area has been discussed in a comparative study of the effectiveness of marine reserves in coral reef management (White, 1986b). Fish surveys and fish yields have been monitored (Alcala and Luchavez, 1981; Russ, 1984; White and Savina, in press a) and Russ (1985) studied fish diversity and abundance in relation to the extent of protection of the area.

**Economic Value and Social Benefits** Apo Island had 900 inhabitants in 1983, mainly dependent on agriculture and fishing. Cultivated plants include coconut trees, corn, sweet potatoes, and cassava. Introduced animals include chickens, hogs, goats, and cattle. The Milkfish *Chanos chanos* is raised in two brackfish ponds. Fishing on the reef occurs throughout the year and at different times of the day depending on currents, winds, and local storms. The fishermen use small, locally-built outrigger boats or "bancas". Their fishing methods include baited hand lines, bamboo traps, gill nets, and spear guns (White, 1984; Savina and White, 1986a). Alcala and Luchavez (1981) estimated the mean annual fish yield of the fringing reef as 16.8 t/sq. km , which is lower than White and Savina's (in press a) more recent estimate of up to 31 t/sq. km. Some inhabitants cater for tourists and divers (White, 1984), and tourism has been increasing following the construction of new facilities (White, 1986a).

**Disturbance or Deficiencies** Illegal blasting and muro-ami fishing was observed in 1977 (UPMSC, 1979) although White (1984) reports that there were no signs of reef degradation from 1981 to 1983. However, some areas are beginning to show the effects of increasing human population. For example, the south-west reef, which fronts the village, is affected by boat anchors, heavy fishing and collecting, and presumably blast fishing done mostly by outsiders. Alcala and Gomez (1985) report that dynamiting ceased in 1985 but that muro-ami fishing still occurred occasionally; this has also now ceased (White *in litt.*, 30.1.87).

**Legal Protection** The entire island, with the reefs to 500 m off shore, was declared a Municipal Reserve in 1985. On the south-eastern side, a 450 m length of coastline and reef, with an area of 11.2 ha, was declared a marine sanctuary. These designations were made under Resolution No. 14 of 1985 and Ordinance No.1 of 3.11.86, Dauin, Negros (MCDP, 1986; White and Law, 1986). Details of regulations are given in the introduction. Apo Island was declared a Marine Reserve and Tourist Zone under Presidential Proclamation 1801, but this has never been implemented in any way.

**Management** Between 1979 and 1980 Silliman University carried out a conservation program to enhance the awareness of Apo residents about sustainable use of their marine resources, using informal education. Once the municipal reserve was established a marine management committee took control (White and Law, 1986). The Philippine Constabulary helps prevent violation of fishing laws and also guards the marine reserve areas against local poaching (White, 1984). A community education centre has been established. Small agroforestry and improved farming projects have been started as an alternative source of income (White, 1986). A brief guide for visitors to the reserve has been produced. This project will continue under the Marine Conservation Project of the Haribon Foundation (White *in litt.*, 30.1.87).

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## APO REEF PROPOSED MARINE PARK

**Geographical Location** Oriental Mindoro, 33 km west of Mindoro Island; 12°37'-44'N, 120°25'-33'E.

**Area, Depth, Altitude** The reef area is approximately 35 sq. km including the two lagoons. Depth of both lagoons is 1.8-18 m; on the seaward slopes, depth exceeds 61 m. Apo Island covers 15 ha and maximum elevation is 6 m.

**Land Tenure** Government-owned.

**Physical Features** The extensive Apo Reef complex is situated on a submerged platform along the Mindoro Strait, which separates Mindoro Island from Busuanga Island in the Calamian Island Group. The reef complex is composed of subtriangular northern and southern atoll-like reefs, which are separated by a 30 m deep channel that is open to the west. The north-east and south-west rims of the two reef structures are straight. Within the two complexes there are two elongate and deep lagoons, the shallow (3-8 m) portions of which are deep mount and funnel fields with isolated coral patches. The lagoons are bordered by narrow reef platforms except on the south-east, where sandy bottoms with depths of 12-23 m predominate (BFAR, 1983; Zacher, 1981).

There are three islands, Apo, Menor (Binangaan) and Cayos del Bajo, which are formed of an older karstified reef of probably Pleistocene age. The recent Apo Reef is only a thin veneer over the older reef. Apo Island is a flat, coralline island approximately 1 km west of the western tip of the southern atoll, separated by a 600 m deep channel. It is thickly vegetated with mangroves, a few coconut trees and some common seashore trees and shrubs, and has a central lagoon of about 10 ha fringed with mangroves. A long white sand beach borders the south-east side and southern tip and a small beach lines the north end. The island is surrounded by a shallow fringing reef of classic morphology, extending some 100-130 m from shore. There is a light-house on the island. The other two islands are large rock outcrops. Menor, the larger of the two, lies on the north-western platform of the southern atoll and has little vegetation. Cayos del Bajo, in the middle of the lagoon of the northern atoll, is bare (BFAR, 1983; White, 1984).

Apo Reef is affected by the rough conditions of both the north-east and south-west monsoons but the north-east side of Apo Island is protected by the atoll reefs. Horizontal underwater visibility over the outer slopes of Apo Island was reported to be around 25-30 m in May (Ross and Hodgson, 1981).

**Reef Structure and Corals** The atolls show a fairly consistent morphology and zonation of corals. The shallowest portions of the narrow reef flats are composed of coral rubble, sometimes overgrown by soft corals, but sometimes with good cover. However, growth of branching and massive corals is poor. In deeper parts (3.2-7 m) of the reef flat, large mounds of *Porites lutea* dominate together with massive *Favia, Goniastrea, Diploastrea*, and *Millepora*. In some areas within the same zone, *Acropora, Hydnophora* and *Millepora* are common. From 7-10 m depth, there may be abrupt changes in slope. Where the slope is regular, *Acropora* and *Pocillopora*, with massive *Favia, Favites, Goniastrea, Diploastrea*, and *Platygyra*, are abundant. The drop-off has high coral cover, mostly encrusting forms of *Montipora, Pachyseris, Merulina, Diploastrea* and *Pavona*. Meandroid forms, *Lobophyllia, Trachyphyllia* and *Euphyllia*, are also found. The deeper portions of the walls have dense growths of *Montipora* and *Pachyseris* (BFAR, 1983).

The fringing reef around Apo Island has a similar zonation to reefs around the atolls. Compared with the north-east reef flat, the south-west or windward side has a deep reef flat with large wave-cut channels. The narrow reef slope, or shallow terrace, has highest species diversity although highest coral cover was found on the upper drop-off and in the back-reef. Ramose forms like *Montipora, Acropora, Pocillopora*, and *Seriatopora*, are common on the shallower reef flats while massive and encrusting forms, like *Porites, Favia, Favites*, and mussids, are found on deeper portions (Ross and Hodgson, 1981).

A survey by the U.P. Marine Sciences Center revealed overall coral cover to be fair (25-50%) to good (50-75%) (UPMSC, 1979). Apo Island Reef is generally believed to be in better physical condition than the atolls (White, 1984). Corals collected in the area are briefly described by Hodgson and Ross (1981).

**Noteworthy Fauna and Flora** Twenty-four species of birds have been reported from the three islands, including terns, egrets, sea eagles, and frigatebirds. The Green Turtle *Chelonia mydas* nests on the beaches. A total of 385 fish species in 85 families have been recorded. Sharks, stingrays, manta rays, barracudas, Giant Bumphead Parrot-fish *Bolbometapon muricatus* and Napoleon Wrasses *Cheilinus undulatus* (BFAR, 1983) are common along the drop-off. A shallow area some 13 miles (21 km) west of Apo Reef known as Hunter Rock has many sea snakes. Rare shells (cowries in particular) and porpoises are found around the reefs (Smith *et al.*, 1982).

**Scientific Importance and Research** The Apo Reef Complex is one of the few atoll formations in the Philippines. Because of its extensive reef area, it was chosen by the Natural Resources Management Center (NRMC) as a test site for experimental studies on the use of Landsat imagery for coral reef inventory work (Biña *et al.*, 1978; Biña and Ombac, 1979; UPMSC, 1979). An invertebrate fauna survey has been carried out (Rosales and Cowan, 1983). Coral diversity and reef zonation are described by Ross and Hodgson (1981) and by White (1984). The distribution of foraminiferans is described by Glenn *et al.* (1981) and the geology of the reef complex by Zacher (1981). White (1986b) discusses the reef in a comparative study on the effectiveness of marine reserves in coral reef management.

**Economic Value and Social Benefits** The waters around Apo Reef are increasingly frequented by commercial and subsistence fishermen. The area is popular with divers, diving tours having been made since 1975, but these have declined recently owing to the damage caused by blast fishing (White *in litt.*, 30.1.87). Facilities for diving are well developed and the reef is readily accessible by boat or air (White, 1984).

**Disturbance or Deficiencies** A noticeable decline in schooling fish has been reported (White, 1984), probably as a result of illegal fishing practices, especially muro-ami. Wide stretches of coral rubble have been observed (BFAR, 1983; UPMSC, 1979) and recently dynamite fishing has had a major impact (White *in litt.*, 30.1.87). Chartered cruise boats are occasionally grounded and the increase in numbers of visiting divers may lead to increasing damage. Large-scale collecting of sea turtles has been reported in the area. Commercial harvesting of shells such as tridacnid clams may pose problems if unregulated. Tern eggs are reportedly taken from the islands by people from Mindoro and northern Palawan (IUCN, in prep.).

**Legal Protection** Apo Reef is covered by Presidential Proclamation 1801 which gives the Philippine Tourism Authority (PTA) the right to protect and develop the area but this has never been carried out. Binangaan Island and Cayos del Bajo have been designated as bird sanctuaries in the management plan for the proposed marine park, and are treated as such by BFAR, but as yet have no legal base (IUCN, in prep.).

**Management** The PTA authorized the Bureau of Fisheries and Aquatic Resources (BFAR) to undertake management studies. In 1983, the Coral Reef Research Team of BFAR established links with the Government and private institutions of Mindoro Occidental for its management. An information centre was established, leaflets produced (Anon., n.d.) and three volunteer park wardens were trained (BFAR, 1983). These efforts have discouraged some destructive activities around Apo Reef (White, 1984).

**Recommendations** The area has been recommended as a Marine Park. A management plan has been drawn up but not implemented. Under this, entry into the Park requires permission from the Park authorities and access to the bird sanctuaries is totally prohibited during the breeding season (June-Aug.). There are two zones: a core zone and a surrounding buffer zone (IUCN, in prep.). The management plan should be strictly implemented and human activities around the reefs and islands should be monitored and limited (BFAR, 1983). Apo Reef could potentially meet the criteria for an International or South-east Asian Marine Heritage site and, if selected, could be managed with financial support and expertise from the UN or ASEAN agencies (White, 1984).

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## BOLINAO REEFS AND PROPOSED SANTIAGO/SILAQUI ISLAND MARINE PARK/RESERVE

**Geographical Location** Bolinao is the northernmost municipality in the province of Pangasinan, bordered on the north and west by the South China Sea and on the east by the Lingayen Gulf, and is often called the "Gateway to the Gulf". It is 300 km north-west of Manila and 25 km north of Hundred Islands, Pangasinan. The area includes Santiago Island (the largest island to the north-east) and several smaller adjacent islands such as Silaqui, Panauan, Tagaporo and Siapar; 16°21'-28' N, 119°53'-120°00' E.

**Area, Depth, Altitude** Santiago Island has an approximate area of 2020 ha, Silaqui of 0.1 ha, Tagaporo of 0.3 ha and Panauan of 0.05 ha. Maximum depth in the channel is 112 feet (34 m) and depth at the fringing reef's edge is 100-150 feet (30-45 m). Highest point in Bolinao is 55 m.

**Land Tenure** Government and private ownership.

**Physical Features** Bolinao is a small, hilly, coastal town surrounded by coconut palms and scrub. A fringing reef lies towards the south-western coast extending roughly 3.5 miles (6 km) down the coast to Balingasay Bay. A strait between Santiago Island and Cape Bolinao forms a perfect typhoon shelter for fair-sized vessels. The entrance is formed by a break in the coral reef which extends 1.6 km off shore north of the town and about 3 km north of Santiago Island (DND-BCGS, 1968). The area opposite the Bolinao Harbour breakwater is rocky. The waters here are turbid as a result of the current systems which accumulate suspended sediments on the leeward side of Santiago Island (NRMC, 1979).

Santiago Island lies north-east of Bolinao, separated by a channel. It is affected by strong winds from the north-east and south-west during monsoon seasons, but it is covered with "ipil-ipil" trees *Leucaena leucocephala*, shrubs and a few mangrove patches. A fringing reef surrounds most of the island, extending northwards approximately 3 km. Silaqui lies to the north, within Santiago's wide fringing reef, and is not subject to strong currents as it lies a considerable distance from the reef breakers. North-west of Santiago, about 800 m from the shore, the reef slopes abruptly to deep waters where sandy substrates, dead corals and rock patches are found. The area is exposed at extreme low water springs. The western reef, opposite Barangay Ducoy, is buffeted by strong waves and strong currents especially during tidal changes. On the southern end of Santiago Island is a channel about 300 yards (274 m) wide which, at depths of up to 11 m, sweeps eastward in an L-shaped pattern to Panauan Islet (29 m). South-eastward of Panauan Island, the channel widens and becomes shallower (NRMC, 1979). Local boats of light draft take advantage of the narrow winding passage leading to Lingayen Gulf from the head of Bolinao Harbour, through Narra, Siapar and Cabarruyan Islands, which are located on the south side of Santiago Island (DND-BCGS, 1968). The channel's substrate is primarily muddy-silt and sand mixture. Tagaporo Islet, located 1 km east of Santiago, is surrounded by a reef flat. Its substrate is typical of seagrass communities consisting of a mixture of mud, sand and coral rubble that extends toward the reef front (NRMC, 1979).

**Reef Structure and Corals** Fringing reefs occur around most of the islands, the most extensive being the one north of Santiago Island. It is a windward reef with a deep east-west channel cutting through the crest on the north-east sector (NRMC, 1979). Silaqui Island has broad areas of seagrass beds (*Thalassia* sp.) located nearshore and wide white sand flats with coral patches and bommies. The reef proper is 3-4 km away from the island and at its outer edge has a luxuriant growth of corals, with a drop-off sloping down to a depth of approximately 85 feet (26 m) (NEPC 1977; MPRPD, 1983).

Of the 15 stations surveyed in Bolinao and its outlying islands, six (35%) were good, eight (47%) were fair and three (17%) were poor in coral cover (UPMSC, 1979). The areas prolific in coral growth are located mainly north of Santiago, including Silaqui and Cangaluyan (located approximately 4 km due east of Santiago). Its 53.8% to 73.4% coral cover consists mostly of *Porites, Galaxea, Acropora, Lobophyllia, Platygyra, Montipora, Goniopora* and *Diploastrea*. Fair coverages ranging from 26.3% to 44% are mostly seen in areas north-west of Silaqui, Bolinao and Points around Santiago Island. Poor coral coverages are surrounded by reef flats dominated by algae and seagrass, particularly around Balingasay and Tagaporo Island. *Millepora* and *Heliopora* are also common, and Organ Pipe Coral *Stolonifera* is common but not dominant.

**Noteworthy Fauna and Flora** The fish populations are reasonable, tending to be more varied and interesting in deeper waters (MPRPD, 1983; UPMSC, 1979). The commonest fish are fusiliers, surgeon fish and parrot fish. Rabbit fish *Siganus* spp. are dominant in the seagrass beds and form a major fishery (UPMSC, 1979).

During field surveys concerning the verification of data obtained from Landsat multi-spectral imagery, 40 species of marine algae were identified; the highest standing crops were observed from February to July (NRMC, 1979). Extensive seagrass communities are found in Silaqui, Santiago and Tagaporo Islands. Some mangrove patches are present at the north-east tip of Santiago Island.

**Scientific Importance and Research** Bolinao and its outlying islands are the principal sites for most of the marine biological research done by the U.P. Marine Sciences Center (UPMSC). A marine research laboratory has been established here. An extensive survey of its reefs was done as part of the project involving the investigation of coral resources in the Philippines (UPMSC, 1979). A similar survey was done by NRMC, although this was mainly through the use of LANDSAT imagery (NRMC, 1979). The UPMSC is carrying out studies on coral growth (e.g. *Acropora pulchra*), coral reef recovery and recolonization and coral transplantation. Various aspects of these studies are reported in UPMSC (1980 and 1982), Yap (1981 and 1983) and Yap and Gomez (1981 and 1984). Artificial reefs using scrap rubber tyres were set-up in November 1978 off Lucero, Santiago Island, to determine feasibility and productivity (Murdy, 1979). Studies on trophic dynamics of coral reefs are being carried out at Silaqui and Cangaluyan Islands. Additional studies include the growth and reproductive biology of Giant Clams *Tridacna* spp., *Strombus*, scallops *Amusium* sp. and rabbitfish *Siganus*

sp. Past research includes an invertebrate and floristic survey of Bolinao and its surrounding islands (Lopez, in press; Saraya, 1979 and 1982).

**Economic Value and Social Benefits** Fishing is the primary source of income around Bolinao. Nets and fish traps are the main methods but dynamite fishing is common in the extensive reef areas of Santiago and other islands. Bolinao is one of the main collecting sites for the aquarium fish trade (Albaladejo and Corpuz, 1981). There is an important shellcraft industry on Santiago Island (Wells, 1982b). A considerable number of tourists frequent Bolinao for its diving sites and white sand beaches and the harbour is used by fair sized vessels (DND-BCGS, 1968).

**Disturbance or Deficiencies** Dynamite fishing, fish collection using cyanide, siltation, and some predation by *Acanthaster planci* contribute to reef deterioration. Detrimental effects have been observed on invertebrates exposed to ichthyocides (Cowan, 1980).

**Legal Protection** None.

**Management** None.

**Recommendations** The fringing reef north of Santiago Island, together with Silaqui Island, has been identified and included among the candidate sites for a possible marine park/reserve (NEPC, 1977). It is recommended that the University of the Philippines, particularly the U.P. Marine Sciences Center, be the lead agency for the task of setting up a management scheme. The area may be included as a pilot Marine Park/Reserve for a new ASEAN-US cooperative project in the Lingayen Gulf area (White *in litt.*, 30.1.87).

## CAGAYAN ISLANDS

**Geographical Location** North-eastern Sulu Sea, some 60-75 km south-west of Panay Island, within the Province of Palawan; 9°35'-9°50'N, 121°11'-121°20'E.

**Area, Depth, Altitude** Dondonay and Cagayan Islands rise to 100 ft (30 m) above sea-level; the other islands are flat. The total area of the pseudo-atoll formation is about 50-60 sq. km. A few kilometers west of the formation, the waters reach 1000 fathoms (1828 m) depth.

**Land Tenure** Government and private.

**Physical Features** The Cagayan Islands are located on the rim of a vast atoll-like formation. The two main islands, Cagayan and Dondonay, lie on the southern rim and are elongated and formed of coralline rock. Other islands include Calalong, between Cagayan and Dondonay; Langisan and Manucan, in the east; Tanusa, north of Cagayan; Boombong, on the north-western tip; Calusa Island, further west of Cagayan; and Cavili and Arena, south-west of Cagayan Island. There is a lighthouse on Manucan Island. The shape of the island complex, its geologic components, and the presence of a lagoon in the centre (between Cagayan and Dondonay) seem consistent with the theory that the island group, along with Tubbataha and other reefs in the Sulu Sea, are part of the volcanic arc (Cagayan Ridge) of the Palawan Island arc system. A piece of pumice rock found on Dondonay Island supports this theory. Several extensive and elongated reefs outline the rim, providing further evidence of an atoll-like formation. These include Igcauayan Reef on the eastern rim, Dauisan Reef on the north-western rim, and Cabantayan Reef on the north-eastern rim (Alcala, 1984a).

During a survey of the reefs in 1984, slightly murky water was encountered, with slow currrents and minimal waves. Deeper areas had clear water. Conditions may not be optimal for diving much of the year as the exposed position of the islands results in frequent strong winds and waves (Alcala, 1984a).

**Reef Structure and Corals** Reef structure has not yet been extensively studied although coral cover has been estimated in some areas by Silliman University. Live coral cover in most parts of the reef north-west of Manucan Island does not exceed 40%, and is probably usually 20-30%. Good cover (70-80%) is found on the southern rim of the island ring, near the junction of the two main islands. The reef on the northern rim, near the coral islet of Boombong, has coral cover of about 50%, and many dead corals, some not yet reduced to rubble, can be seen. A drop-off on the western side of Cagayan Island has good to excellent cover, estimated at 50-60% and 80-95% on the steeper parts, for a length of about 1.5-2.0 km along the shore (Alcala, 1984a).

**Noteworthy Fauna and Flora** The uninhabited islets serve as rookeries for seabirds and the isolated beaches as nesting grounds for marine turtles (NEPC, 1977). A species of Chambered Nautilus, which appeared smaller than *Nautilus pompilius*, has been caught in traps at depths greater than 100 m off Manucan Island. Three species of tridacnids *Tridacna squamosa, T.maxima* and *T.crocea*, have been recorded. Species diversity for fish is reportedly high (Alcala, 1984a).

**Scientific Importance and Research** The area warrants further detailed research as carried out on Tubbataha and Apo Reefs, since atoll-like formations are not common in this region. A general description of the Cagayan and surrounding islands is given in MPRDP (1983). Calusa Island has been claimed to be one of the best diving sites in the world by German and American divers who previously surveyed the area. A coral reef survey has been carried out by Silliman University (Alcala, 1984a).

**Economic Value and Social Benefits** Fishermen frequent the area using hook and line, lift nets and illegal methods such as muro-ami and dynamite fishing. Manucan Island is inhabited by transient fishermen from the islands of Panay, Negros and Bohol. Collection of *Nautilus* and tridacnids has been reported (NEPC, 1977). Tourists may frequent the area but this has yet to be documented.

**Disturbance or Deficiencies** The use of illegal fishing methods is common since enforcement is lacking due to the area's isolation. *Acanthaster* occurs at a high density (about 10 large individuals per 4 sq. m) around Cagayan and Dondonay Islands and extensive predation was observed (Alcala, 1984a).

**Legal Protection** The Cagayan Islands are within the Palawan Game Refuge and Bird Sanctuary and the Palawan Mangrove Swamp Forest Reserve and, as small offshore islands, were declared National Reserves under Presidential Proclamation 219. (They were *not* declared a Marine Sanctuary in 1970, cf. White, 1981).

**Recommendations** Implementation of existing regulations on the islands is required. The Province is subject to future ground truth surveys and delimitation for conservation and protection of flora and fauna including marine life (Hunting Technical Services, n.d.).

## CARBIN REEF (SAGAY) MUNICIPAL PARK

**Geographical Location** Visayan Sea, about 0.5 km (5 km?) north-east of Old Sagay on Negros Island, and 9.5 km west of Molocaboc Island, to the north of Negros Island; 10°59'N, 123°27'-123°28'E.

**Area, Depth, Altitude** Approximate area 2.0 sq. km (reef is 2 x 1.4 km); greatest depth 12-15 m; a part (0.5 x 0.1 km) of the sand cay is exposed at low tide; area of Municipal Park is 154 ha.

**Land Tenure** Municipality of New Sagay, Negros Occidental.

**Physical Features** The cay is surrounded by a somewhat oval-shaped reef flat, elongated in the north-south direction and which slopes gradually from 3 m to 10 m depth. The reef is surrounded by water 12-15 m deep. Average water temperatures at the surface are about 26-27°C. Prevailing winds are from the north-east from November to April and from the south-west from May to October. The north-east monsoon frequently brings strong gusty winds that prevail for weeks, rendering the reef inaccessible to fishermen.

**Reef Structure and Corals** Data from a 1983 survey by Silliman University Marine Laboratory showed the following live and dead coral cover: live soft corals 0.0-6.25; live hard corals 14.3-75.0; dead corals 10.0-54.3; coral rubble 4.3-29.3; rock 1.25-35.0, and sand 0.6-12.5. As a result of dynamite fishing, live hard coral cover varied widely, ranging from practically zero to as high as 75%. The following corals were found on the southern reef: *Porites, Favia, Acropora, Pocillopora, Favites* and *Heliopora*; on the west side, *Acropora, Porites, Fungia, Heliopora, Millepora* and *Pocillopora* were recorded; on the north *Porites, Acropora, Pocillopora, Favia, Favites*, and *Millepora* were recorded. In general, coral diversity was fairly high. By January 1985, there was noticeably more live coral cover, fish and molluscs and the reefs appeared to be recovering (Alcala, 1985).

**Noteworthy Fauna and Flora** There is now a fairly high diversity of reef-associated species, including the Blue-Spottted Stingray (Dasyatidae), goatfish (Mullidae), damselfish (Pomacentridae), butterflyfish (Chaetodontidae), surgeonfish (Acanthuridae), groupers (Serranidae), triggerfish (Balistidae), parrotfish and pufferfish (Tetraodontidae). The brown alga *Turbinaria* and green algae grow well on dead corals and are fed on by several species of herbivorous fish. Giant clams *Tridacna* of three species are found in significant numbers. Several species of sea cucumbers, as well as squids and cuttlefish, are present. The absence of terrestrial plants makes the cay inhospitable to terrestrial animals and only seabirds have been observed.

**Scientific Importance and Research** Carbin Reef is a study site for Silliman University Marine Laboratory, particularly for reef research. Following a request from the Municipal Council of Sagay, it was surveyed by BFAR (1980). If created a sanctuary, this would be a suitable site for long-term studies on coral growth and biological studies of associated organisms.

**Economic Value and Social Benefits** Carbin Reef is an important fishing area for fishermen from Negros. There is potential for reef-related tourism (Alcala, 1985).

**Disturbance or Deficiencies** Carbin Reef is generally easily accessible by motorized and non-motorized small boats. Dynamite fishing occasionally occurs, despite the presence of guards. Typhoons may be damaging, but the extent of this has not been quantified.

**Legal Protection** Under Municipal Resolution No.59, 1983 of the Sagay Municipal Council, legal protection was provided for Carbin Reef (Alcala, 1985).

**Management** Management is sporadic. A caretaker has been assigned to prevent fishing. The watch tower, which was erected for this purpose, is also used as a base by researchers. BFAR has carried out a number of coral reef conservation seminars (Castañeda and Miclat, 1981).

**Recommendations** The municipality of Sagay has recommended the establishment of a Municipal Park to generate wide co-operation from both local and national offices and organizations. Since the area lies outside municipal waters, BFAR plan to enact a Fisheries Administrative Order authorizing the Council to establish a fish sanctuary (Castañeda and Miclat, 1981). It would be administered by the Municipal Government of Sagay, which has shown willingness and an ability to police it. Fishing, gleaning and the collecting of sand or any form of marine life should be prohibited. The boundaries should be clearly defined and marked with buoys. Studies on the impact of the sanctuary on the surrounding reefs, where fishing is allowed, should be conducted. Guidelines on the use of the sanctuary/park by tourists should be drawn up. However, at present these recommendations are not being followed up.

## DANAJON BANK PROPOSED MARINE PARK/RESERVE

**Geographical Location** In the Camotes Sea, Central Philippines, extending along the northern coast of the island of Bohol. Danajon Islet lies at 10°16'N, 124°37'E. The inner barrier of the double barrier reef is some 3 miles (5.5 km) north of the municipality of Jetafe, on the northern tip of Bohol.

**Area, Depth, Altitude** Low-lying islands (about 1 m in altitude) are found on some of the reefs. The outer barrier is 80 nautical miles (148 km) long. The average width is about 1.5 mi. (2.8 km) but the reef portions exposed at low tide do not exceed 1 mi. (1.8 km). The average depth of the central area is 1.5 m. The inner barrier is 14 nautical mi. (26 km) long and 1.5 mi. (2.8 km) wide (Pichon, 1977a).

**Physical Features** The Danajon Bank is a double barrier reef (Pichon, 1977a). The outer barrier is composed of three elongated reefs 12, 12 and 14 nautical miles (22, 22 and 26 km) long, extending east to west, and separated by narrow passes. To the north it is more fragmented and is composed of a series of five smaller isolated reefs with low islands. It lies on the margin of the continental shelf and the reef drop-off is continuous with the fore-reef slope. Depths of 400 m are found less than 1 mile (1.8 km) from the reef front (Pichon, 1977a).

The inner barrier is less continuous than the outer barrier but its central part is composed of a single unit, opposite the towns of Jetafe and Talibon, Bohol. The lagoon between the barriers is 29-37 m deep in the centre and 1-2 mi. (1.6-3.2 km) wide. A few patch reefs, pinnacles and coral knolls occur in the outer lagoon, but most of the floor is covered with sandy mud or soft mud (Pichon, 1977a). Numerous islets are found on the bank, including Pandanon Islet, the two Caubyan Islets on the outer barrier, Tood Islets at the east end of the bank, and Danajon Islet. These are low, small, wooded, and covered with bushes (MPRDP, 1982a). Minantao Reef is a small patch reef lying within the double barrier reef (Hodgson and Ross, 1981).

The Danajon Bank is well protected from intense hydrodynamic action due to the enclosed location of the Camotes Sea. It has been suggested that the double barrier developed through unique tidal currents and/or resumption of subsidence after the outer barrier was formed (Pichon, 1977a). Grobe *et al.* (1985) studied the double barrier.

**Reef Structure and Corals** The outer slope of the outer barrier generally has a gentle upper slope about 500-800 m wide down to a 15 m depth and a lower, vertical slope down to 50 m. The upper slope has about 50% coral cover with *Pavona cactus* and *Anacropora* dominating. Fungiids are particularly abundant on hard and soft bottoms and include species such as *Halomitra philippinensis*. The lower drop-off is composed of horizontal overhangs where *Leptoseris* dominates. Ahermatypic forms, like *Tubastrea* and *Dendrophyllia*, occur under the overhangs (Pichon, 1977a).

The reef flats of both inner and outer barriers are similar. The external part of the reef flat on the outer barrier is covered mainly with corals of various growth forms (massive, digitate, or branching). The seagrass beds of both barriers are often interrupted by sandy areas where acroporids, pocilloporids, faviids, and *Millepora* grow (Pichon, 1977a). The back-reefs of both barriers are composed of sandy slopes colonized by large coral heads. The back-reef of the outer barrier has indented coral-built margins, sometimes descending by a series of steps toward the lagoon floor and colonized mostly by *Anacropora, Porites, Echinopora, Pachyseris*, and *Pectinia* (Pichon, 1977a). Hodgson and Ross (1981) describe corals collected at Minantao Reef.

**Noteworthy Fauna and Flora** The drop-off on the outer barrier has large reef-dwelling fish and occasional rays and sharks may be seen (Smith *et al.*, 1982). Alcyonarians, *Sarcophyton* and *Xenia*, are particularly abundant on the outer slope. The seagrass beds are dominated by *Thalassia hemprichi* and *Enhalus acoroides* (Pichon, 1977a).

**Scientific Importance and Research** Danajon Bank is famous for its unusual double barrier reef morphology. Pichon (1977a) gave a detailed description of the area and concluded that the present structure can be interpreted as being an example of a degraded stage (by hyperaccumulation of sediments) of the coral reef evolutionary series. In 1980/81, the double barrier was studied by a group from the University of Kiel, West Germany, in cooperation with the University of San Carlos, Cebu (Wefer, 1985). The area has been surveyed by the BFAR as a candidate site for a marine reserve (MPRDP, 1982a).

**Economic Value and Social Benefits** Fishermen from Romblon, Mindoro and Marinduque regularly fish these waters. Aquarium fish collecting has been reported (MPRDP, 1982a). An experimental farm for the commercially valuable red alga *Eucheuma spinosum*, a source of carageenan, was set up on the north-western bank in 1975. By 1979, there were 200 farm houses/platforms constructed, 500 hectares planted, 15 million plants in the water, 2000 people working daily in the farms, and 8000 people or 1000 families living on the banks fully or partly dependent on income from farming seaweeds. It is being studied as possible seedstock for numerous *Eucheuma* farms on the reef flats of the western outer barriers (Lim and Porse, 1981).

**Disturbance or Deficiencies** The area is subject to considerable damage from illegal fishing, especially dynamite fishing. Coral gathering was common before the 1977 ban (MPRDP, 1982a). The immigration of sea farm workers onto the banks and the seaweed farming activities may add to the disturbance of the area.

**Legal Protection** None.

**Management** None.

**Recommendations** Danajon Bank has been included in the list of candidate marine park or reserve sites (MPRDP, 1982a and 1983). It has recently been proposed as a reserve by the NRMC and is considered a priority site but as yet has received no management (White *in litt.*, 30.1.87).

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## DOS HERMANAS

**Geographical Location** 12-15 nautical miles (22-28 km) south of Gasan, Marinduque Island; under the municipal jurisdiction of Corcuera (Jones), Romblon, located to the south-east; 13°1'N, 121°54'E.

**Area, Depth, Altitude** Total area of islands 45 ha; maximum altitude is 70 m (Isabel Island); maximum depth of fringing reefs 30+ metres.

**Land Tenure** Government-owned.

**Physical Features** Dos Hermanas is a pair of islands two nautical miles (3.7 km) apart, oriented east-west. The larger westernmost island is Carlota; the other is Isabel. Both islands are flat-topped with coastal limestone cliffs approximately 30-40 feet (9-12 m) high (MPRPD, 1983). Carlota has a short strip of beach on the north-east. Both islands are sparsely covered with Cogon *Imperata* and scrub. Carlota has a cultivated area, adjacent to the beach, planted with corn, cassava and bamboo. The substrate is clay mixed with pebbles and coralline materials. The cliffs on both islands are almost vertical and are pock-marked with caves and crevices. Visibility underwater is 100' (30 m).

**Reef Structure and Corals** Carlota Island is bordered by a fringing reef which is steeply sloping except on the north side, where the island has a rocky beach and the reef slopes gently down to 20 fathoms (36 m). Isabel Island is ringed by a narrow fringing reef on all sides. At a distance of one to two kilometres on the south and south-west of both islands are reef patches and white sand that slope gradually (NEPC, 1977; MPRPD, 1983).

Coral cover is good, ranging from 40 to 80%, with branching forms of *Acropora* sp. predominant. The reef slopes on the eastern side of both islands have abundant colonies of alcyonarians; off Carlota, there is an extensive community of stinging hydroids. On the western side of Carlota, where the coral cover is best, the reef slopes down to 20-33 m where encrusting and massive coral species predominate.

**Noteworthy Fauna and Flora** The Coconut Crab *Birgus latro* is found and is considered a delicacy by the inhabitants of Marinduque (MPRPD, 1983). The fringing reefs abound with pelagic fish, large groupers and other reef-associated species. Porpoises are seen regularly, to the west of the islands (Smith *et al.*, 1982). There are large populations of terns, gulls and other seabirds, which nest in the cliffs.

**Scientific Importance and Research** The area has not yet been studied.

**Economic Value and Social Benefits** The area is used by fishermen from Gasan and Buenavista municipalities in Marinduque, and from Mindoro and Romblon. A half-built water cistern that is part of the discontinued lighthouse complex on Isabel Island provides water (NEPC, 1977; MPRPD, 1983).

**Disturbance or Deficiencies** Not known.

**Legal Protection** None.

**Management** None

**Recommendations** Dos Hermanas was considered a candidate marine park/reserve site (MPRPD, 1983). Fishing activities in the area should be regulated, but the area is no longer considered a priority for management (White *in litt.*, 30.1.87).

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## EL NIDO PROPOSED MARINE PARK

**Geographical Location** Bacuit Bay, north-west corner of Palawan Island; between Malampaya Sound, to the south, and the northern tip of Palawan, about 30 km to the north; 11°00-11°15'N, 119°15'-119°20'E.

**Area, Depth, Altitude** Bacuit Bay covers approximately 150 sq. km; depths within the bay gradually increase seaward to 40 m near the entrance; islands in the bay reach a max. elevation of about 400 m while the mountains surrounding the bay reach to above 500 m.

**Land Tenure** Government and privately owned. Most of the land surrounding the bay is within a commercial logging concession.

**Physical Features** The bay is exposed to the effects of both the north-east and south-west monsoons, but typhoons are rarely experienced. The islands at the mouth of the bay tend to block the major effects of long period swells built up during the monsoons but localized high winds, combined with refracted long period waves, can create waves 1-2 m high on occasion. A more detailed analysis of the weather conditions in Bacuit Bay is being carried out. Currents within the bay are relatively sluggish, being tide and wind-driven. Outside the bay more rapid 3-4 knot currents may be encountered in the narrow straits between islands.

There are six islands within the bay and eleven islands immediately outside, formed of limestone which has been eroded into fantastic patterns, with 300 m high vertical cliffs intersected by numerous exposed caverns. Two main rivers enter the bay, one at the north and one at the south, and two more smaller rivers enter opposite Binagboyoton Island, near the village of Manlag.

**Reef Structure and Corals** The islands are surrounded by fringing reefs, and there are many patch reefs. Reef flats in this area are generally exposed during extreme low tides, and have very low coral cover with silt and sand predominating. The reef edges have highest coral cover (which can approach 100% for sediment-resistent species) and this gradually decreases as the depth increases. In some areas, coral cover rapidly approaches zero at depths as shallow as 6 m. The bottom is composed of several meters of deep silt.

In the cleaner water of the central bay, patch reefs and reef flats are dominated by many species of *Montipora, Porites, Coeloseris, Favia, Echinopora* and *Goniastrea*. Coral diversity increases over the reef edge and down the slope to a point where sedimentation effects are again apparent and coral cover gradually declines to zero at 15 m depth.

Many of the reefs around the islands at the mouth of the bay have reef flats with 90% coral cover and sheer drop-offs to 50 m depth. Shallow reefs here have a very high diversity of *Acropora* with large table forms. On the reef slopes and walls, coral and fish diversities equal or surpass those found at more distant pristine sites such as Apo Reef or Tubbataha Reef. The fringing reefs along the outer islands generally have a narrow shelf-like reef flat and then a steep to sheer slope down to 30 m. In some areas a second drop-off begins after a second shelf and drops to 70 m depth. In these areas large pelagic fish are common as well as large reef fish such as Napoleon Wrasse *Cheilinus undulatus* and groupers *Epinephelus* spp. Transects of wide reef areas have shown overall coral cover of approximately 30%.

**Noteworthy Fauna and Flora** A fish feeding station has been set up by one of the diving resorts and it is not uncommon to see 30 large groupers, jacks (Carangidae), needlefish (Belonidae) and barracuda *Sphyraena* spp. swarming, as well as the normal complement of smaller reef fish. Sharks (Selachimorpha), dolphins (Delphinidae) and Bryde's Whales *Balaenoptera edeni* as well as manta (Molubidae) and sting rays (Dasyatidae) are common sights along the reefs outside and at the mouth of Bacuit Bay. Saltwater crocodiles *Crocodylus porosus* are rarely seen in the rivers now, but Dugongs *Dugong dugon* still occur, a group off 60 having been sighted in 1986. Turtles are still common.

**Scientific Importance and Research** As a result of the inaccessibility of Bacuit, little more than anecdotal reports were available until a recent study was undertaken on the effects of increased sedimentation on the marine life due to logging. In 1986 an informal survey of the bay was conducted by a research team from the University of the Philippines Marine Science Center, who collected data on coral cover, fish and coral generic diversity and the location of *Tridacna* populations.

**Economic Value and Social Benefits** The main population centres are the town of El Nido, north of the bay, and the village of Manlag at the back of the bay. Fishing is an important activity both for commercial purposes and for the needs of the local inhabitants, the main catches being squid and anchovies. Tourism is growing rapidly. An international dive resort with Japanese backing has been in operation for several years and another smaller operation has recently opened.

**Disturbance or Deficiencies** The marine environment is virtually pristine although some outer reef areas are damaged by strong wave action in bad weather. *Acanthaster* are present but not abundant. Sedimentation from increased logging and slash and burn agriculture is a major threat to the reefs. Logging operations started in 1985 in the northern sector of the concession and by 1986 about one third of the area bordering the bay had been cleared. Logging was halted during 1986 but began again in January 1987. Large scale coral and mollusc die-offs have been recorded on nearshore reefs which correlate with increases in turbidity and sediment deposition, but it is not yet possible to predict the extent of this damage. There is a plan to build a road to the town of El Nido, previously only accessible by boat or air, which would open up the area to further development.

**Legal Protection** None, apart from national fisheries legislation.

**Management** Realizing that the success of their resort depended on a pristine marine envirinment, the management of the international diving resort coordinated with various government agencies, including the Armed Forces, the local police, the Coast Guard, Navy and Bureau of Fisheries, to improve enforcement of fisheries legislation in Bacuit Bay. The resort has provided boats for patrols, fuel and provisions for the enforcement officers. Regular illegal fishing operators have moved elsewhere, particularly as the resort was prepared to fund the resulting court cases. Activities such as dynamite fishing and illegal trawling are being successfully prevented. The diving resort helps divers to avoid damaging popular dive sites. Spearfishing and the collection of any marine life by tourists is strictly prohibited.

**Recommendations** The area is proposed as a Marine Park under the Strategic Environmental Plan for Palawan (Hunting Technical Services, 1985 and n.d.). Given the importance of the marine environment of Bacuit Bay and the availability of timber resources in other parts of the country, it would seem a wise precaution to limit logging in the surrounding area. Viable alternatives to slash and burn agriculture have been introduced in the Central Visayas and a priority should be placed on similar training and extension work in this area. Tourism development should be carefully planned. Some form of tourist "head tax" could be considered to fund law enforcement and management plans directly. It is hoped that buoys will be made available at popular dive sites to minimise anchor damage.

N.B. This account has been compiled by G. Hodgson and is based on information collected in the course of a 1986 project in Bacuit Bay; it was received at the time of going to press and so has not been reviewed.

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## FORTUNE ISLAND

**Geographical Location** Approximately 10 naut. mi. (18 km) west of the municipality of Nasugbu, Batangas Province; 14°04'N, 120°34'E.

**Area, Depth, Altitude** The island is approximately 30 ha; the surrounding waters have a maximum depth of 80 ft (24 m).

**Land Tenure** The island is reportedly leased to private individuals.

**Physical Features** The island is generally rocky. About 35% of its vegetation is natural forest; the remaining 65% is classified as disturbed forest and is made up of 35% secondary growth forest, 15% open grassland and 15% barren area. There is a long sandy beach on the south-east and the rest of the island is fringed by steep cliffs, which drop vertically into the water and appear to be the result of tectonic or volcanic activity. On the east there is a wide fringing reef extending approximately 200-250 m off shore. Off the northern eastern side is a "blue hole". This consists of a series of holes at 40-45 ft (12-14 m) which lead into a wide archway that emerges at 75 ft (23 m) depth (Smith *et al.*, 1982). A sunken coral shoal known as the Simo Banks is situated 10-12 naut. mi. (18-22 km) off the northern tip of the island.

**Reef Structure and Corals** Coral cover around the island is fair with 20-30% hard coral cover and 30% soft coral cover. Hard corals occur in patches off the western side of the island; the physiography is sloping, with corals growing close to the bottom and constituting good cover (MPRDP, 1983). Branching corals have the highest percentage coral cover but diversity is quite low. *Acropora* is dominant.

**Noteworthy Fauna and Flora** Fish diversity is high with large populations of various taxa such as parrotfish Scaridae, barracuda Sphyraenidae, groupers Serranidae and small sharks. Terrestrial fauna consist of some rare field rats, rock lizards and birds (MPRDP, 1982a).

**Scientific Importance and Research** No information.

**Economic Value and Social Benefits** The area is frequented by fishermen, campers, divers and swimmers; Cathedral Rock is a popular dive site (Hodgson *in litt.*, 9.2.87).

**Disturbance or Deficiencies** Commercial fishing and aquarium fish collecting are carried out in the area.

**Legal Protection** Fortune Island was declared as a Tourist Zone/Marine Reserve under Presidential Proclamation 1801 but has never been established as such.

**Management** Although the area is theoretically administered by the Philippine Tourist Authority, it has not implemented any management. However, it is reported that local resort owners are urging the police to patrol the area with them to apprehend illegal fishermen (Hodgson *in litt.*, 9.2.87).

**Recommendations** May be proposed as a marine reserve (White *in litt.*, 30.1.87).

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## FUGA ISLAND MUSEUM

**Geographical Location** In the Babuyan Channel, approximately 20 nautical miles (37 km) north of the municipality of Claveria, Cagayan Province, Northern Philippines; 18°50'-18°55'N, 121°13'E.

**Area, Depth, Altitude** The island has an approximate area of 115 sq. km (20 x 6 km); highest point is Mt Nanguringan at 191 m.

**Land Tenure** Reported to be privately owned by the Taggat Lumber Company (MPRDP, 1983).

**Physical Features** Fuga Island is in the Babuyan Islands, north of Luzon Island. It is an elongated island (east-west axis) with two small islands, Barit and Maybag, located on the western side. Irao Island lies approximately 10 km to the north-east (NEPC, 1977). On the south side currents may reach 7-8 knots (13-15 km/hr) and 8 ft (2.4 m) swells are common (Smith *et al.*, 1982). A drop-off of about 100 feet (30 m) starts from a shallow platform on the south face and a series of caves can be found at the base.

**Reef Structure and Corals** Three stations were surveyed on Fuga and the surrounding islands (UPMSC, 1979). Maybag had fairly good coral cover ranging from 43.2% to 61.25% on both northern and southern sides. Barit Island had fair coral cover of 37.5%. No signs of destruction were observed. Dominant coral genera observed included *Porites, Acropora, Favia, Favites, Diploastrea* and *Galaxea*. Fuga is ringed by a fringing reef with very high coral cover. On the western side, opposite Barit Island, is a barrier reef dotted with coral mounds 12-15 fathoms (22-27 m) deep (MPRDP, 1982a).

**Noteworthy Fauna and Flora** The surrounding waters are rich in pelagic gamefish, e.g. marlin, tuna, sailfish, wahoo, etc., which are attracted to the Kuro Shio Current (NEPC, 1977). Sharks, particularly Hammerheads, Black-tips and White-tips, as well as some species of barracudas, are present in moderate numbers. There is a strong indication of precious coral beds in the vicinity (NRMC, n.d.). The island is noted for its lobsters.

**Scientific Importance and Research** Fuga Island has been surveyed in connection with the project of the U.P. Marine Sciences Center "Investigation of the Coral Resources of the Philippines" (UPMSC, 1979).

**Economic Value and Social Benefits** Fishing is the main source of livelihood for the inhabitants of Fuga Island (MPRDP, 1982). It is one of the best venues for sport fishermen and sport divers who are attracted by the rich assemblage of pelagic fish; the south side is a popular diving site (Smith *et al.*, 1982).

**Disturbance or Deficiencies** Taiwanese precious coral poachers have been observed in the area (MPRDP, 1983).

**Legal Protection** Fuga Island was declared a Tourist Zone and Marine Reserve under Proclamation 1801 but has never been established as such. In addition, Fuga and surrounding islands have been declared an Underwater Museum under Proclamation 1744. Fishing and collection of any marine life form is prohibited, but regulations have never been enforced.

**Management** Control and administration of tourist policies lie with the Philippine Tourism Authority (NEPC, 1977; MPRDP, 1983). The Philippine Navy and Coast Guard are expected to enforce regulations (MPRDP, 1983) but there has never been any management.

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## HONDA BAY PROPOSED MARINE PARK

**Geographical Location** About 8 km north-east of Puerto Princesa, on the eastern side of Palawan Island; 9°50'-10°N, 118°44'-119°E.

**Area, Depth, Altitude** The bay is approximately 28 000 ha. The shallow reef environment reaches 7-18 m depth. The islands are flat and rise just above sea level.

**Land Tenure** The islands are government-owned and have not yet been subjected to land classification; at present, they are leased to private individuals for coconut cultivation.

**Physical Features** Honda Bay is a large body of water with twelve islands scattered within it. The bay is quite exposed to the open sea and is relatively shallow, sloping down to 24 fathoms (49 m) in the middle. Reefs in the area include fringing reefs, patch reefs and some shoals. Some patch reefs have sand areas with mangrove stands and are known by local names such as Marcelo Island, Pulding Island and Isla Puting Buhangin. Some of the islands are part of larger, reef-island complexes, such as the reef complex connecting Kalungpang, Parunponon and Buguias Islands (total area of reef: 879 ha), the Meara-Fraser Islands reef complex (452 ha), and the Makesi Island reef (389 ha). Some of these reefs have lagoons which are only accessible at high tide, such as the two small lagoons in the Meara-Fraser Island reef and the lagoon in the Kalungpang-Parunponon Buguias Island reef (NRMC, 1984b). A general description of the area and islands is given in Bruce (1981).

The waters of Honda Bay are free from strong ocean currents and are relatively safe and calm. North-east monsoon winds affect the waters from November to February, decreasing visibility. The south-west monsoon season (most pronounced from June to August) does not affect the area much. Very calm and glassy smooth waters may occur between February and April. The Tandayak and Babuyan Rivers discharge on the northern coast of the bay.

**Reef Structure and Corals** The fringing reefs have very wide and often shallow reef flats, frequently many times larger in area than the islands they surround. The exposed parts of these flats consist mostly of sand and coral rubble but the more enclosed areas may have mangroves. The submerged areas of the platforms may be barren or may be inhabited by corals such as *Porites, Acropora* and *Millepora*. On most flats, algal mats and seagrass beds are found in patches. The reef flats may reach 6 m depth but are usually around 1-3 m (NRMC, 1984b).

Seaward of the flats are slopes and sometimes vertical but short drop-offs, as in Bush Island, Arrecife Island and Fondeado Island. The reef slopes are often gradual, reaching 6-19 m depth (Fraser Island) or undetermined depth (Fondeado Island). Most of the slopes are sandy or rocky and overgrown by *Porites, Montipora, Acropora, Turbinaria* and *Fungia*, the soft corals *Sarcophyton, Lobophyton, Xenia, Anthelia* and *Dendronephthya*, gorgonians, whip corals and sponges. Foliate forms of *Turbinaria, Pachyseris* and *Montipora* predominate in deeper areas (NRMC, 1984b). Coral cover was estimated at 40-63% (UPMSC, 1980). Soft coral cover is greater than hard coral cover. *Sarcophyton* and *Lobophytum* are the commonest soft corals, and *Porites, Acropora, Millepora, Turbinaria, Pachyseris* and *Montipora* are the commonest hard corals.

**Noteworthy Fauna and Flora** Canon Island has a large bat population. Seabirds are common in the bay and include sandpipers, herons, egrets, eagles, crested terns and kingfishers. Sea turtles and sea snakes are occasionally sighted. Honda Bay is rich in mangrove resources (1500 ha). Visual surveys revealed around 279 species of fish representing 41 families, including bumpheads, barracudas and stingrays. The most common families are Pomacentridae, Caesiodidae, Chaetodontidae, Pomacanthidae, Labridae, Scaridae, Lutjanidae and Acanthuridae (NRMC, 1984b). Invertebrates of commercial use are present, such as sea cucumbers, large bivalves and cuttlefish. Algae and seagrass are abundant in the bay, especially on the reef platforms and shallow sandy areas.

**Scientific Importance and Research** Several biological surveys have been and are being conducted, primarily to supplement the data needed for recommending the area as a possible marine park/reserve. An initial biological survey and socio-economic study of coastal barangays of the area was made by the Marine Parks Reserve Development Plan Technical staff (MPRDP, 1984). Several research projects dealing with mariculture, such as seaweed and oyster culture and grouper raising, are underway. A priority research area has been identified at the mine tailings discharge areas of the non-operational Quicksilver Mine (NRMC, 1984b).

**Economic Value and Social Benefits** There are 19 barangays in the Honda Bay vicinity and the main sources of income are agriculture (mainly coconut) and fishing. Fishing activities include: subsistence fishing (with nets, spears, hook and line, and fish corrals), and collecting of sea cucumbers and fish for the aquarium trade. Mariculture of some organisms is underway. The bay area is frequented by tourists who are attracted by the natural beauty of the environment and its easy accessibility (MPRDP, 1984).

**Disturbance or Deficiencies** Although the bay is still productive, the fish yield is reported to be declining due to intensive fishing activity in the area. Illegal practices such as dynamite fishing, trawling and use of cyanide have been reported. The mangrove areas are being converted to fishponds which may ultimately affect the reefs. Tourism, if unchecked, may become detrimental (NRMC, 1984b; Bruce, 1981), and is already reported to have caused damage to some reefs. Corals are collected and there has been some damage due to siltation from the estuary of the Bacungan River (Hunting Technical Services, 1985).

**Legal Protection** The area lies within the Palawan Game Refuge and Bird Sanctuary and the Palawan Mangrove Swamp Forest Reserve. Presidential Proclamation 1801 declares the area of Honda Bay as a Tourist Zone and Marine Reserve, but it has never been established as such.

**Management** The area is theoretically administered by the Philippine Tourism Authority and illegal fishing practices should be brought to the attention of the Municipal Government of Puerto Princesa or to the Bureau of Fisheries and Aquatic Resources (BFAR), but it is not clear if there is any real enforcement.

**Recommendations** A management plan is being drawn up by the MPRDP Staff. It includes a zoning plan in three phases, which will aim to establish core areas (Ramesamey, Pulding and Taginit reef areas), to serve as sources of genetic material for the surrounding areas, and buffer areas, which with the core areas will provide opportunities for reasonable use consistent with conservation of marine resources. Human activities are to be monitored and controlled by the following entities: Reserve Inter-Agency Task Force, the Marine Parks/Reserve Development Program Technical Staff, the Municipal Government of Puerto Princesa, the Marine Park Field Staff, the local enforcement agencies of the Municipality, the Bureau of Fisheries and Aquatic Resources, the Bureau of Forest Development, and the Armed Forces of the Philippines (WESCOM) (MPRDP, 1984). The area has also been proposed as a Marine Park under the Palawan Environmental Strategic Plan (Hunting Technical Services, n.d.). Recommendations for management of the area are also given in Bruce (1981).

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## HUNDRED ISLANDS NATIONAL PARK

**Geographical Location** On the south-west coast of the Lingayen Gulf, extending some 4 km north of the municipality of Alaminos, Pangasinan Province, Luzon; about 30 km south of Bolinao, Pangasinan; 16°11'-16°15'N, 120°02'E

**Area, Depth, Altitude** Maximum depth recorded between the islands is 10 fathoms (18 m). Islands range from about 10 m to about one mile (1.6 km) in length. Area of National Park is 1845 ha, of which 150 ha is land.

**Land Tenure** Government-owned.

**Physical Features** Hundred Islands is a cluster of about 90 small, wooded, mushroom-shaped islands in the Lingayen Gulf. The limestone base and sides of many of the islands are undercut by wave action, forming low precipitous and overhanging cliffs. The upper portions of the islands show some karst features. White sandy beaches are found on the sheltered shores of larger islands, such as Quezon Island in the north. On islands to the south, towards the mainland, soil may cover the steep slopes of the shore, and the overhanging or vertical rock cliffs are less conspicuous. Many of the islands have only narrow reef-flats, with adjacent coral communities sloping steadily at 40-50° to a depth of only 30-45 feet (9-14 m) where silt is encountered (Meñez, 1961; UPMSC, 1979). The geology of the area is described by Schoenberger (1986). The climate is similar to that of Bolinao, Pangasinan (*see separate account*). Mean annual rainfal is 2500 mm peaking in August, and the driest month is January (IUCN, in prep.).

**Reef Structure and Corals** Reef structure and zonation patterns have not been studied although UPMSC (1979) surveyed coral cover around 10 islands using 14 transects. Moderate coral cover of 21.9-30% was found around the northerly islands but live coral cover was poorer in the south, ranging from 5 to 25%. Quezon Island had a fair living coral cover of around 45%. Coral diversity was relatively low. In the more exposed northern section, table and massive *Acropora* were dominant, while in the silty central and southern portion, silt-resilient forms, such as *A. aspera, Pachyseris, Porites, Fungia*, and faviids, were dominant. There are few reefs remaining now (White *in litt.*, 30.1.87).

**Noteworthy Fauna and Flora** Reef fish such as Moorish Idols *Zanclus cornutus*, surgeonfish Acanthuridae, fusiliers Caesiodidae, damselfish Pomacentridae and some chaetodontids are found. There is a diverse invertebrate fauna and extensive seagrass beds (Carrascal de Celis, 1977). Marine algae are described by Meñez (1961). The vegetation on most of the islands is quite sparse. Mangroves (predominantly of the genus *Rhizophora*) may be found between islands near the mainland.

**Scientific Importance and Research** The Hundred Islands form an unusual geological formation which is the subject of current geological research (Schoenberger, 1986). The marine vegetation has been surveyed (Carrascal de Celis, 1977).

**Economic Value and Social Benefits** The Hundred Islands are a major tourist attraction. White sandy beaches, a sunny tropical climate and coral communities provide sunbathing, swimming and snorkelling. There are accommodation and tourist facilities and "cabanas" in Lucap, the village opposite the islands, and on some of the islands themselves. The sale of souvenir items provides additional income to people in the area. The Lingayen Gulf provides a sheltered anchorage at 6 to 8 fathoms (11.0 to 14.6 m) in the west (DND-BCGS, 1968). In March 1951, a landing was constructed at Lucap for fishing and transport vessels.

**Disturbance or Deficiencies** Siltation may be a problem in the area. It is influenced by silt-laden discharge from various rivers which flow into the Lingayen Gulf. Tourist activity may present problems if proper management programs are not formulated and implemented. Illegal activities such as the collection of corals and dynamite fishing have been reported (UPMSC, 1979).

**Legal Protection** Hundred Islands was proclaimed a National Park under Presidential Proclamation 667 in 1940 and by P.D. 564. Since it is not a marine park, the reefs may not fall within the protected area.

**Management** At present there are no clear guidelines for management of the marine environment but a "conceptual" management plan has been prepared for the area as part of the NEPC Coastal Zone Management Programme (Tolentino, 1984). The area was originally under the Bureau of Forest Development (Parks and Wildlife) but is now managed in a minimal fashion by the Philippine Tourism Authority.

**Recommendations** Hundred Islands has been proposed as one of the candidate marine parks/reserves (MPRDP, 1982a). The tourist potential of the area makes a zoning management scheme necessary. Boat traffic should be regulated and co-ordinated around the islands. Preventive measures are needed to minimize siltation.

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## MACTAN ISLAND AND EASTERN FRINGING REEFS

**Geographical Location** A few km east of Cebu City, Cebu Island; 10°20'N, 124°E.

**Area, Depth, Altitude** Mactan Island is about 10 m above sea level; Hilutangan Channel has a maximum depth of 188 fathoms (340 m).

**Land Tenure** Government and privately owned.

**Physical Features** Mactan is a coralline island. The eastern fringing reef has a steep drop-off to a sand tallus slope at about 30 m. Ross (1984) and Sy *et al.* (1981) propose the following zonation: an algal and seagrass reef flat about 50-210 m wide (at 0-1 m depth); an upper and lower reef crest at 1-10 m depth, and a fore-reef wall or drop-off (at 10 m). The Buyong and Maribago area covers a little over 25 ha, of which 75% consists of narrow sandy beaches and 25% of limestone outcrops. The Amboucuan/Marigondon area lies on the south-east side of Mactan and has strong currents; a drop-off is found at about 100 m from shore at a depth of 40 feet (12 m) and there are caves at 90-120 feet (30-40 m).

A elongated reef, supporting Olango Island, and the adjacent smaller southerly islands of Lassuan, Caohagon and Panganan, lie to the east of Mactan, separated by the Hilutangan Channel. Interesting coral formations are found down to 60 ft (18 m), below which there are occasional caves (Smith *et al.*, 1982). Poo and Sta Rosa, on Olango Island, facing Mactan, have large expanses of shallow reef flats, with drop-offs starting at around 30-40 feet (9-12 m). Relatively strong currents flow between Olango and Mactan (Smith *et al.*, 1982).

**Reef Structure and Corals** Qualitative surveys in 1977 (UPMSC, 1979) showed poor coral cover (0-25%) in some areas off Marigondon, Maribago, and Buyong, but in others, such as opposite the University of San Carlos Marine Station, there was fair to good cover (25-75%). Detailed studies of coral community structure in Maribago, Buyong and Punta Engaño may be found in

Ross (1984) and Sy *et al.* (1981). Algal and seagrass reef flats are regularly interrupted by coral patches of *Pavona decussata* and *Cycloseris patelliformis* (Sy *et al.*, 1981) contributing around 70% of the 15% live coral cover in this zone. *Porites* and *Montipora* spp. dominate the reef crest which has a fair live cover (Ross, 1984; Sy *et al.*, 1981). Coral composition and abundance may have decreased and changed as a result of recent typhoons (Bolanos and Aliño, 1984). Olango reef flat was investigated in the course of a multidisciplinary study carried out by the University of Kiel (Wefer, 1985).

**Noteworthy Fauna and Flora** Fishermen collect rare shells, such as *Conus gloriamaris*, in the area. There are occasional sightings every year of Whale Sharks *Rhinocodon typus* (Smith *et al.*, 1982). A preliminary list of marine algae is given in Liao and Sotto (1980). Carpenter *et al.* (1981) studied fish diversity at reefs off Buyong Beach, off the south-west tip of Olango Island and in the Hilutangan Channel. The University of San Carlos Marine Research Office (Cebu City) has surveyed the marine fauna.

**Scientific Importance and Research** The work carried out by the University of San Carlos Marine Station at Maribago makes this area of scientific interest. Several Unesco workshops and training courses have been held here including one on Shallow Water Ecosystems (Schramm *et al.*, 1981). A number of taxonomic studies have been carried out, including corals (Hodgson and Ross, 1981; Nemenzo and Ferraris, 1982), molluscs (Lopez and Zambo, 1979; Sotto and Cosell, 1982), and marine algae (Liao and Sotto, 1980). In 1980/81, an interdisciplinary study of material flux between the water column and the seabed was carried out in the Hilutangan Channel and adjacent areas by the University of Kiel, West Germany, in cooperation with the University of San Carlos (Wefer, 1985).

**Economic Value and Social Benefits** Rau (1979a) describes small-scale fishing in the area. Tourism has increased in recent years and Mactan has become one of the more popular holiday destinations in the Visayas. Hotel resorts, private cottages and chalets are found along many beaches. Boat hire and the souvenir trade (shell handicrafts, etc.) provide additional sources of income. Buyong and Maribago reefs are popular with divers, and Panguian Point and Punta Engaño on the south-east have been suggested as possible dive sites (Smith *et al.*, 1982). Diving is also popular off Olango Island.

**Disturbance or Deficiencies** The recent typhoons "Nitang" and "Bising" had a major impact on the east side of Mactan (Bolanos and Alino, 1984). Moyer *et al.* (1982) suggested that there has been some damage to corals due to predation by the gastropod *Drupella rugosa*. Cebu City is the second largest city in the Philippines and Mactan Island is the site of an international airport. Boat traffic and other tourist activities may cause problems both on land and in the water. Ross (1984) reported that illegal harvesting of living hard corals for the export trade may be affecting the abundance and colony size of some commercially important species in the Malingin area, Punta Engaño. Rau (1979b) describes the possible impact of pollution on fishing. Damage from fishing using explosives and the muro-ami and kayakas techniques has also been reported (Carpenter and Alcala, 1977).

**Legal Protection** Buyong Beach on the south-east side of Mactan and the adjacent islands of Olango, Lassuan, Coahagon, and Panganan were declared as Tourist Zones and Marine Reserves under Presidential Proclamation 1801 but have never been implemented as such.

**Management** The Tourist Zones and Marine Reserves come under the jurisdiction of the Philippine Tourism Authority but law enforcement has been lax, particularly as far as the coral trade is concerned (Wells, 1982a and b).

**Recommendations** The identification and involvement of various interest groups (e.g. resort owners, University of San Carlos, townspeople) in a management program is necessary. Co-ordinated efforts are needed to implement zone schemes and to establish navigational routes and waste disposal areas. Other amenities are needed, such as adequate freshwater supply, toilets, and health services, including a centre which can deal with diving accidents.

## MOALBOAL/PESCADOR ISLAND PROPOSED MUNICIPAL PARK

**Geographical Location** Central western coast of Cebu Island; Tañon Strait lies to the west, separating Cebu Island from Negros Island; Pescador Island lies 4 km south-west of Moalboal; 9°56'-10'N, 123°22'E.

**Area, Depth, Altitude** The Moalboal Peninsula extends 5 km in a north-south direction and is fringed on the west by a reef extendng 18-100 m from shore. The drop-off levels off at an average of 130 feet (41 m). Pescador Island has an area of approximately 1.5 ha and is fringed by a reef flat extending 610 feet (193 m) from north to south. A lighthouse is found on the highest point of the island (19 m).

**Land Tenure** Government and privately owned.

**Physical Features** The west coast of the peninsula is sheltered from the south-west monsoon by Negros Island, and north-east winds and easterly storms rarely affect the coast. The beaches have a flat limestone formation, with rocky outcrops behind, and a narrow strip of white sand. Pescador Island is a small limestone island with rock and cliff shores surrounded by a fringing reef with a shallow, narrow reef flat, a reef crest, and a fore-reef drop-off (White, 1984).

The current along Tañon Strait is strong and flows north or south, depending on the tide. Currents at 60 ft (18 m) may flow in the opposite direction to the surface currents at Saavedra, the northernmost "barrio" on the peninsula (Smith *et al.*, 1982). Pescador experiences stronger currents and waves due to its more open location. Visibility is good in both areas (up to 30 m at Tapanan, on the southern end of the peninsula) since there is no freshwater run-off near the beaches and the peninsular location of the reefs protects them from silt from Cebu rivers (White, 1984).

**Reef Structure and Corals** The marine environment is described in White (1984) and further details on reef structure are given in Smith *et al.* (1982). The fringing reef along most of the peninsula has a high diversity of hard corals on the shallow, inner reef flat, fore-reef, and reef crest. The drop-off slopes steeply (70-90°) at Panagsama Beach from an edge at 10 m depth, and levels off at about 41 m. Highest coral cover is generally found on the reef crest and fore-reef. The inner reef flat is partially sand-covered and sand predominates near shore. The reef slope has decreasing coral cover and diversity with depth, and gorgonians predominate in deeper water. Submarine caves are encountered at around 80-100 feet (25-32 m), especially along Saavedra and Bas Diot (the central section of the peninsula). The reef off Panagsama Beach has good hard coral cover (32.5%) and fair soft coral cover (23.4%). Protected from winds and waves, the reef crest grows near the water surface and the shallow reef has a flat topography. Branching and foliose corals dominate and hard coral diversity is high (50 genera). Damage from storms and *Acanthaster* predation is low and overall the reef condition is good.

The steep fore-reef drop-off of the fringing reef around Pescador Island begins at 5 m and levels off at around 29-35 m. Buttresses are encountered on the western slope at 18 m, including a huge, funnel-like formation known as Pescador Cathedral, which drops to 35 m and is 15 m in diameter. The Pescador Island Reef had fair hard coral cover (39.3%) dominated by branching forms. Rubble cover was higher than at Panagsama Reef, probably reflecting dynamite fishing. The reef is flat, which may account for the low species diversity (White, 1984). A separate study showed good coral cover on Pescador Island Reef (60%), which is dominated by branching corals (UPMSC, 1979). Encrusting corals, foliose corals, and gorgonians are common on the slopes.

**Noteworthy Fauna and Flora** Large sea snakes have been reported from Saavedra and large groupers (Serranidae) have been encountered at the entrances of some of the caves. Stonefish (Synanceiidae) are known to reach substantial sizes and small sharks abound in deep water around Pescador Island (Smith *et al.*, 1982). Schooling fish are found in high diversity on the fore-reef drop-offs. Chaetodontid diversity was used by White (1984) as an index of reef condition. Panagsama's reefs have 21 chaetodontid species compared to 11 species on the reefs around Pescador Island.

**Scientific Importance and Research** Pescador Island was studied in 1978 as part of the project "Investigation of the Coral Resources of the Philippines" (UPMSC, 1979). White (1984) included Moalboal/Pescador Island in his dissertation on marine parks and reserves and also in a comparative study of the effectiveness of marine reserves in managing coral reefs (White, 1986b).

**Economic Value and Social Benefits** Most of the reefs are fished by the local inhabitants of the barrios. Fish resources are rich due to the fringing reefs and the estuarine nutrient sources to the south and north of Panagsama (White, 1984). Most fishermen use hook and line, although gill nets and fish traps are also used. Fish traps have recently been discouraged by resort owners because they damage the coral. Shells are collected for sale to tourists, and fishermen often charter their boats for day trips.

Tourism has grown rapidly in the area, in some places becoming more important than fishing. There are about eight hotels with a combined capacity of 300-400 guests at Panagsama Beach alone. However, the majority of visitors are local divers who come from Cebu City for photography and spearfishing.

**Disturbance or Deficiencies** Although illegal fishing methods such as dynamiting are still used in the area, especially at Pescador Island, the main disturbance seems to be collecting, spearfishing, anchor damage and other disturbances by tourists. Corals around Pescador Island were damaged by Typhoon Nitang in September 1984 and have been slow to recover (Alcala, 1985).

**Legal Protection** Destructive fishing methods, particularly dynamite fishing and fish traps, which are lowered over the reef edge, have been banned from the beach front and on the nearby Pescador Island Reef by an ordinance drafted by the Mayor of Moalboal in 1980 in response to complaints from resort owners.

**Management** The beach communities, under the jurisdiction of Moalboal, have elected barrio captains but local affairs seem to be dominated by the resort owners, who say that the barrio captains do not represent their needs. The resort owners have contributed to conservation by persistently monitoring the area and informing fishermen of what is damaging to the reef, besides enforcing the ordinances drafted by the Mayor of Moalboal (White, 1984).

**Recommendations** The rich marine environment of Moalboal and Pescador Island needs to be managed. Human disturbances could bring about a change in the attractiveness of the marine environment to tourists in the next five years. There is a need for local co-ordination backed by financial and legal assistance from national agencies. Besides giving legal support for local regulations, the town of Moalboal could also zone the area for different tourist and fishing uses, leaving some areas undisturbed. Active participation of all resort owners in a beach front association could effectively protect the nearshore reef. Enforcement problems could be referred to the local constabulary detachment. Financial assistance might come from a small tourist tax, collected and administered locally, and/or from yearly grants from the national marine task force (White, 1984).

## PANGLAO PROPOSED MUNICIPAL RESERVE AND BALICASAG MUNICIPAL RESERVE

**Geographical Location** Panglao Island lies some 800 m south-west of Tagbilaran City, the capital of Bohol; Panglao municipality is on the south-west coast of the island at 9°35'N, 123°45'E. Balicasag Island is about 8 km south-west of Panglao Island; 9°31'N, 123°41'E.

**Area, Depth, Altitude** Panglao has an area of 5590 ha (18.5 x 7.4 km), Mt Biking on the eastern side being the highest point (163 m); surrounding waters reach depths of more than 30 fathoms (55 m). Balicasag has an area of 30 ha and maximum altitude of about 3-5 m above sea level; surrounding waters drop to about 100-150 ft (32-47 m). The water between the two islands reaches depths of 357 m.

**Land Tenure** Balicasag is owned by the Philippine coastguard.

**Physical Features** Balicasag Island is a low, flat, oval island of rock and coralline substrate surrounded by a sand-shell coralline beach. A fringing coral reef rings the island, varying in width from 50 m to about 200 m at the 10 m isobath. Steep slopes descend from the reef on all sides except the south-east, where there is a more gradual sand slope (White, 1984). A lighthouse is located near the centre of the island.

Panglao is an oblong-shaped and generally flat coralline island oriented north-west. The town of Dawis lies on the north-eastern tip, connected to Tagbilaran City by two causeways, one at the north-west and the other at the south-west end. The town of Panglao lies on the south-west coast facing Panglao Bay, which is partially enclosed by a wide reef. This extends seaward towards the south-south-west for approximately 4-5 km before veering back eastward to the island, creating a lagoon. Only small pumpboats can cross the reef to the lagoon even at high tide. The lagoon is 1 m deep at low water and has a substrate composed of mainly white sand and seagrass flats. Sixty to seventy percent of the reef is exposed at low water. On the south side of the lagoon are two vegetated islets - Pungtud and Gakang. Due west of Pungtud, the reef terminates in perpendicular submarine cliffs which drop to over 30 fathoms (55 m).

The shallow reef flats of Balicasag and Panglao have scattered eelgrass patches (MPRDP, 1983). The area is affected more by the south-west than by the north-east monsoon. Clear waters were observed in a survey along Doljo Point, the northern tip of Panglao Bay, and there were no strong currents (UPMSC, 1979). Visibility at Balicasag approaches 50 m vertically when calm. A temperature of 32°C was recorded in September (White, 1984).

**Reef Structure and Corals** On the northern and western sides of Balicasag Island, the reef is narrowest and slopes gently to a depth of 5-10 ft (1.5-3 m) from where a sheer cliff drops 100-150 ft (30-45 m) to a slope of sand and coral rubble. The drop-off is notable for large sea fans, black corals and underwater caves. The reef crest forms a distinct shallow band and generally has good coral cover in deeper parts (White, 1984). The dominant corals are *Montipora foliosa, Pocillopora* sp. (branching and table), *Acropora* sp. and massive *Porites* sp. Coral diversity is high at depths of up to 80 ft (25 m) with an average 60% coral cover. The south side of the island has alternating slopes and drop-offs which usually start at 60-80 ft (19-25 m). Coral cover on this side is fair with an average of 40% (MPRDP, 1983). White (1984) found poor coral cover (21.2%) around Balicasag but a high diversity of 144 species.

The reef front on the south-west side of Panglao has coral cover of 30%-80%, composed of branching, table and massive forms, with branching and table *Acropora* spp. dominant. Living coral cover on the perpendicular cliffs consists of massive and encrusting forms (*Porites* sp., *Acropora* sp.), huge gorgonians 5-6 ft (2 m) wide, and whip corals at depths of 80-90 ft (25-28 m). The rest of the surrounding reef platform consists of sandy slopes of 30 to 45°, with scattered mounds of coral and seagrass patches. A survey at Doljo Point (northern tip of Panglao Bay) showed 50% hard coral cover (UPMSC, 1979).

**Noteworthy Fauna and Flora** Pilot Whales, Giant Rays, Green Turtles *Chelonia mydas* and sharks are occasionally spotted in the area. Huge schools of carangids, caesios, and surgeonfish have been encountered at Balicasag and large groupers and Napoleon Wrasses are found at the base of cliffs (White, 1984). Balicasag is also well known for rare shells such as *Conus gloriamaris, Cyprea guttata* and *C. valencia*. The large whip corals and gorgonians on the drop-offs of Panglao and Balicasag are well-known.

**Scientific Importance and Research** The marine habitats of Panglao and Balicasag were surveyed by the BFAR Coral Reef Research Team in 1976, and by the Marine Parks Inter-Agency Task Force in 1978 (White, 1984). The U.P. Marine Sciences Center surveyed the reefs in Panglao as part of their investigation of the coral resources of the Philippines (UPMSC, 1979). Balicasag Island was surveyed by White (1984) as part of his dissertation and used in a comparative study on the effectiveness of marine reserves in the management of coral reefs (White, 1986b). Russ (1985) studied fish diversity and abundance on reefs around Balicasag in relation to degree of protection.

**Economic Value and Social Benefits** Balicasag is inhabited by about 50 families and Panglao has two municipalities, Dawis and Panglao (MPRDP, 1983). Fishing and shell gathering are the main occupations on Balicasag. Shell collecting accounts for 70-80% of the fishermen's income and the shells are sold directly to buyers in Cebu City, to dealers from Cebu or Balicasag, or directly to tourists (White, 1984). The populace of Panglao are mostly farmer-fishermen. Shallow gill nets, bamboo fish traps, spears, and hook and line are used and there is some shell collecting. The sea urchin *Tripneustes* sp. is gathered for its gonads and exported to Japan via Cebu (MPRDP, 1983). Balicasag has been popular with SCUBA divers since the 1970s. Since 1980 it has been frequented by an increasing number of divers on dive tour boats from Cebu City and Manila and on local dive boats (White, 1984). There are several beach resorts on Panglao.

**Disturbance or Deficiencies** Coral collecting and the use of poison for aquarium fish collection has been recorded in Balicasag (MPRDP, 1983). Probable causes of destruction of reefs, particularly the reef flats at Doljo Point, are wave action, *Acanthaster* predation and dynamite fishing (UPMSC, 1979). The increase in dive tour boats is probably causing added pressure from shell collecting and spearfishing (White, 1984).

**Legal Protection** In July 1986, with the assistance of the MCDP programme of Silliman University, a Municipal Reserve was approved by the Panglao town council under municipal ordinance extending 500 m off shore around Balicasag; a fish sanctuary of 8 ha lies within it on the south-west shore (White and Law, 1986). Panglao and Balicasag have been declared Marine Reserve/Tourist Zones under Presidential Proclamation 1801. Balicasag Island is a government reservation for the Philippine Coastguard Lighthouse Service.

**Management** The BFAR Coral Reef Research Team has conducted several marine conservation seminars on

Panglao and has visited Balicasag informally (White, 1984).

**Recommendations** Strong links should be formed between local residents and outside implementors of management schemes. The community must be approached about its priorities for maintenance of the reef and improvement of fish catches. They may want to regulate or prohibit fishing in certain areas which are attractive to SCUBA divers. Tourists may provide the necessary incentive for local support of reef management. Formal management is unlikely to be implemented immediately as the area is third on a list of other non-implemented Marine Parks (White, 1984). A municipal reserve is being planned in front of the town on Panglao (White *in litt.*, 30.1.87).

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## PUERTO GALERA BIOSPHERE RESERVE

**Geographical Location** Northern tip of Mindoro Island; 120 km south of Manila and 30 km from Batangas City; bounded to the north by the Verde Island Passage, to the south by the municipality of Mamburao and Sta Cruz, Occidental Mindoro, to the east by San Teodoro and to the west by the municipality of Abra de Ilog, Occidental Mindoro; 13°23'-13°32'N, 120°50'-121°00'E;

**Area, Depth, Altitude** Total area of reserve is 23 247.23 ha (Gonzales, 1984) or 23 545 ha (Bardach, 1979). The highest point is Mt Malasimbo (1800 m); it is not clear whether the reefs are included within the reserve.

**Land Tenure** Goverment and private ownership.

**Physical Features** The area is generally hilly or mountainous, backed by the Cabarian Ridge and Mt Malasimbo. The coast is largely cultivated for coconuts; it is 42 km in length, irregular and indented with numerous coves (Gonzales, 1984). Medio Island, off the north coast, separates Manila Channel on the west and Batangas Channel on the east at the entrance to Puerto Galera Bay.

The coastline includes muddy flats, coral reefs, mangrove coves, and rocky and sandy shores. The almost land-locked Puerto Galera Bay has three extensive coral reefs referred to as the First, Second and Third Plateaus, and numerous coves rich with mangrove growth. On either side of the Bay are white sandy beaches stretching from east to west and interspersed with rocky cliffs (Gonzales, 1984; University of the Philippines, 1982); coves include Lalaguna, Sabang, Minolo Bay, and Balatero Cove located due west, and Varadero Bay to the south-east.

The climate is relatively dry from November to April and wet during the rest of the year with a mean annual rainfall of 2625 mm. The warmest months are April and May and the coldest are December and January (Maralit, 1984). Typhoons may occur but are not generally severe (Velasquez, 1976).

**Reef Structure and Corals** Puerto Galera has been surveyed as part of an assessment of coral resources in the Philippines (UPMSC, 1979). Eighteen stations were studied, two of which (Varadero Bay and a small bay north-east of the Second Plateau) were reef areas according to the map but turned out to be sandy with seagrass beds. Only one station, due north of Lalaguna Point, has excellent coral cover (78%). The corals are mainly *Porites, Acropora, Millepora, Turbinaria, Galaxea* and faviids, and there are patches of rubble and sand at depths greater than 45 ft (13 m). Eight stations were poor in hard coral cover (0-23%), mainly the areas of Medio Island (south and west side), First Plateau, Minolo Bay, Balatero Cove (western tip) and Taupan Pt. Faviids, *Acropora* spp. and alcyonarians were most abundant. The remaining stations including areas in Sabang Cove, Escarceo Pt, Paniquian Pt and the northern tip of Medio Island, ranged from fair to good coral cover (34-62%). All five coral suborders are represented and Astrocoeniida, Fungiida and Faviida are dominant; *Millepora* spp. are common.

A similar study was carried out by the Puerto Galera Committee (University of the Philippines, 1982). Coral abundance was relatively high in stations outside Puerto Galera Bay (Sabang, Sinandigan and Markoe Cove) but extremely low inside the Bay, including the two extensive reef flats, First and Second Plateau. Almost all the drop-off areas surveyed were rich in reef building corals at depths of 20-50 ft (6-15 m). An early description of the coral fauna is given in Nemenzo (1955). At that time, coral was abundant at Paniquian and Medio Islands.

**Noteworthy Fauna and Flora** Invertebrates such as hydroids, gastropods, crustaceans, echinoderms and alcyonarians are represented, the latter being dominant (UPMSC, 1979). Several species of seagrasses are present, *Thallassia* sp. being the most abundant (University of the Philippines, 1982). Among the algae, the Rhodophyta (e.g. *Gracilaria, Acanthophora, Hypnea,* etc.) are commonest. The terrestrial part of the reserve includes a wide variety of endemic species (Unesco, 1986).

**Scientific Importance and Research** The variety of habitats found in Puerto Galera makes it ideal for field studies (Gonzales, 1984; University of the Philippines, 1982; Velasquez, 1976). The University of the Philippines has maintained a biological station in the area for the use of its students since 1930, although at present the building is unusable. Man and the Biosphere (MAB) inter-agency members have carried out inventory work and environmental monitoring (Gonzales, 1984; Maralit, 1984; NEPC, 1977), although plans for further research have not been implemented (Unesco, 1986).

**Economic Value and Social Benefits** Although tourism has been developing rapidly, many people still depend on fishing for their livelihood (Gonzales, 1984). The following coastal areas are important for subsistence fishing: Big and Small Tabinay, Escuada, Punta Buaya, Palangan, Sinandigan, Balatero, San Isidro, Asinan and Talipanan. Most of these areas are also sites for Milkfish *Chanos chanos* fry gathering in May, June and July. Marble is mined in some areas, particularly in the two barangays of San Isidro and Dulangan. Sand used to be taken from the white beaches of Honduras, San Isidro, Sabang and Lalaguna, but this has ceased for the present.

Puerto Galera has been one of the most important tourist resorts in the Philippines since the early 1970s and many of the 1682 households in the area are involved with the industry. Sabang, Lalaguna (Big and Small), White Beach (San Isidro) and Poblacion are the main centres, but Talipanan, Balatero, Tabinay and Baclayan are becoming increasingly important (Gonzales, 1984). Beach cottages have been built and the harbour area is being developed (Wells, 1982b).

**Disturbance or Deficiencies** Puerto Galera's marine environment is under threat from increasing tourist activity and careless field work by students, and the majority of reefs have been disturbed (Gonzales, 1984; Maralit, 1982; University of the Philippines, 1982; Velasquez, 1976). These activities, as well as mining for sand and, inland, for marble, have resulted in siltation and alteration of beaches, subsequently affecting water circulation and causing increased sediment transport. For many years, vessels discharged their waste into the waters but this has been curbed. The constant traffic of small craft (about 500 pumpboats operate in the bay) continuously agitates the bottom, increasing water turbidity in some areas. Anchor damage is apparent. Corals are collected for lime production, the lime being used in the construction of small ship hulls to prevent leakage (Gomez, 1980; Wells, 1982b). Oil effluents reach the beach from the refinery in Batangas (Wells, 1982b). The drop-off areas are seldom subjected to coral collecting or trampling but there is occasional dynamite fishing, particularly in Balatero Bay, Balaytigue and at Escarceo Pt.

**Legal Protection** Puerto Galera was declared a Man and Biosphere Reserve under Presidential Declaration 354 of 26 December 1973 and accepted as a Biosphere Reserve by Unesco in January 1977. Proclamation 1801 of November 1978 declared Port Galera, Balatero Cove and Medio Island as Marine Reserves and Tourist Zones (NEPC, 1977; MPRDP, 1983).

**Management** The Philippine Tourism Authority (PTA) has been given some control and administrative powers over tourist activities in Puerto Galera.

**Recommendations** It was expected that the PTA would delineate areas with potential value for tourism, promulgate rules and regulations subject to the approval of the President and co-ordinate the integrated development of the area for the optimum use of natural assets and existing facilities (NEPC, 1977; MPRDP, 1983).

The University of the Philippines has come up with the following recommendations: (1) conservation measures should be strictly enforced; (2) there should be a general limitation on and regulation of the exploitation of natural resources; (3) students should not be allowed to collect marine organisms; (4) existing mining concessions should be phased out and no new ones granted; (5) denuded areas should be reforested; (6) feasibility studies should be carried out to determine zones and the transfer of the existing dock to Balatero Bay should be completed; (7) studies should be carried out to determine the extent of pollution; and (8) the U.P. Marine Biology Station should be relocated to a less congested area. A report by the Pacific Area Travel Association Task Force includes a recommendation for further development of Puerto Galera as a major tourist destination (PATA, 1982). In the 1970s, the National Museum was given responsibility for establishing an interpretative centre in the town (Berdach, 1979) but the proposals and plans were never followed up.

## SICOGON ISLAND PROPOSED MUNICIPAL MARINE PARK

**Geographical Location** In the Visayan Sea; about 10 km east of Estancia on mainland Panay, 53 km north-west of Carbin Reef, and 86 km north-east of Banago, Bacolod and Negros Occidental; 11°25'-11°28'N, 123°13'-123°16'E.

**Area, Depth, Altitude** Approximate land area of 6.0 sq. km; c. 8.0 sq. km reef around the island. Depths immediately beyond the reef crest 22-31 m. The highest peak is about 318 m.

**Land Tenure** The island is owned by the Vice Mayor of Carles and is within the jurisdiction of the municipality of Carles, Iloilo Province, Panay Island.

**Physical Features** Sicogon Island is generally hilly and on the east is well covered with monsoon forest. There is a spectactular peak, capped with scrubby vegetation near the centre, and brushwood and grasses cover much of the northern, western and southern hillsides. There are freshwater streams and a narrow lagoon cuts through the northern part of the island. The uninhabited islet of Tumaguin lies about 250 m to the north-east, and is hilly, with practically no flat land, and capped with forest. The lower areas are overgrown with Cogon and probably "talahib". Sicogon Island and Tumaguin Islet both have white sand beaches. Several coral reefs are found within a radius of eight km of Sicogon Island.

The prevailing winds are from the north-east from November to April and from the south-west from May to October, but part of the island is always sheltered. The island is sometimes hit by typhoons during the rainy months from August to December.

**Reef Structure and Corals** In 1985, a team from Silliman University Marine Laboratory established three sampling stations at depths of 2-8 m on the eastern reef of Sicogon. These showed the following percentages of live soft and hard coral cover and dead coral and rubble: live soft corals 0.0-10.0, live hard corals 12.5-24.3, dead corals 18.1-20.6, coral rubble 5.0-26.2, rocks 6.8-49.3, and sand 5.0-42.5. A fairly high coral species diversity was observed. South-east of Tumaguin Islet, the dominant live corals are *Platygyra, Porites, Favia, Favites, Coeloseris, Symphyllia, Lobophyllia, Goniopora, Pocillopora, Acropora, Seriatopora* and *Millepora*. East of Sicogon, the coral community includes: *Porites, Platygyra, Heliopora, Favia, Favites, Symphyllia, Goniopora, Galaxea, Lobophyllia, Acropora, Millepora* and *Hydnophora*. To the south at Gasang, soft corals, *Porites, Favia, Favites, Goniopora, Acropora, Montipora, Pavona, Millepora* and *Galaxea*, are dominant. Coral relief in all three areas ranges from a few centimetres to one metre from the bottom.

**Noteworthy Fauna and Flora** Most of the eastern hills are covered with primary forest that spreads down to the shore; there are no mangroves. The marine fauna includes Giant Clams *Tridacna*, clown fish, butterfly fish, sergeant majors, apogonids, anthiids, triggerfish, goatfish, wrass, catfish, rabbitfish, stingrays, groupers, puffers, fusiliers, etc. Young groupers, an indicator of heavy fishing pressure (Russ, unpublished manuscript) were seen all over the reef. Gorgonians and sponges are abundant from 10 to 25 m depth on the south-eastern part of Tumaguin Islet. *Padina, Sargassum* and other brown algae are found on rocks in shallow water.

**Scientific Importance and Research** The area has great potential for research and is accessible from Panay which has a number of universities and colleges. Silliman University Marine Laboratory and the University of the Philippines Marine Sciences Institute have investigated the reefs. The former is continuing to monitor the progress of the reef protection programme in cooperation with the resort owner (Gomez *in litt.*, 12.2.87).

**Economic Value and Social Benefits** Weather permitting, Sicogon Island is accessible either by boat or aircraft throughout the year and is a major tourist area with a resort. Fishermen live on Sicogon and are under the responsibility of one leader. Coconuts are cultivated on Tumaguin, and on Sicogon the fishermen have farm lots.

**Disturbance or Deficiencies** Corals may have been damaged by divers at popular dive sites and littering is becoming noticeable on the reefs. Local observers report that some of the coral destruction may be due to dynamiting by fishermen as there is no enforcement of regulations. The low percentage of live coral cover found during the Silliman University survey could be due to siltation or dynamite fishing.

**Legal Protection** The Vice Mayor of Carles has prohibited dynamite fishing.

**Management** The owners of the Sicogon Island Tourist Resort are convinced of the need to manage the reefs in order to attract tourists and provide more income for local people. They have initiated a move for greater awareness and conservation of part of the Sicogon Reef.

**Recommendations** The eastern reef of Sicogon from Tumaguin Islet to 4 km south-east of Sicogon has been proposed as a Municipal Marine Park for Carles, Iloilo. It would be administered by the municipal government of Carles. Fishing, gleaning and collecting of sand or any form of marine life in the park should be permanently prohibited. Boundaries should be clearly defined and marked with buoys. Studies on the impact of the sanctuary on the surrounding reefs where fishing is allowed should be conducted. Guidelines on the use of the sanctuary/park by tourists should be drawn up.

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## SOMBRERO ISLAND PROPOSED MARINE PARK

**Geographical Location** North-western tip of Maricaban Island, south-west of Calumpan Peninsula, Batangas Province. Sombrero lies in the Verde Island Passage between Batangas Province and Mindoro Island and is situated approximately 130 km south of Manila and 7 km south-west of Anilao, Batangas; 13°42'N, 120°49'E.

**Area, Depth, Altitude** The island covers 1.3 ha and has a steep (45°) elevation to about 145 ft (44 m). Depth ranges from 2 fathoms (3.6 m) on the shallow water platform surrounding the island to a maximum of 38 fathoms (69.5 m).

**Land Tenure** Government-owned.

**Physical Features** The island is hat-shaped (hence the Spanish name) and is underlain by horizontally embedded units of tuffaceous sandstones, wackes, and conglomerate, capped by basaltic flows and ejecta. The tuffaceous sediments and the basaltic capping all belong to the Calatagan Marl Formation of the Pleistocene Age. Recent deposits of beach sand composed of shell and coralline fragments are prominent on the eastern side, a result of sediment deposition due to the relatively protected nature of this side. Large boulders resulting from cliff and slope erosion are found on the northern, western, and southern sides (MPRDP, 1981).

Sombrero Island experiences two pronounced seasons: dry from December to April, and wet during the rest of the year. The wettest months are from July to September while the driest months are February and March. Two major wind systems directly affect the area: the north-east and south-west monsoons. North-easterly winds often prevail with a mean speed of 4 kph. The area is affected by about six of the typhoons entering the Philippine area annually. The general current direction is westerly to north-westerly throughout the year and is essentially wind-driven, but the tides account for current speeds which reach 6 kph.

The platform surrounding the island resembles the "rim" of a hat. On the northern and southern sides, it curves down in a gradual slope; in the west it extends seawards for 200 m before dropping off sharply as a steep wall from about 12 to 20 m. Much of the east side consists of a steep sandy slope from the shore to about 30 m depth. The south side has a coral covered platform as on the north and west, which stretches about 50-100 m seawards before a steep drop-off (MPRDP, 1982b; McManus *et al.*, 1981).

**Reef Structure and Corals** The island is considered to be surrounded by coral communities rather than fringing reefs because of the absence of wave-breaking crests, or spur and groove systems (MPRDP, 1981). The platform can be divided into distinct north, east, south and west coral communities.

The north community is very irregular, extending for some 500 m before becoming predominantly sand and coral gravel. Massive *Porites* heads, *Acropora* tables and soft corals dominate the area above 12 m and encrusting and foliose forms predominate along the slopes. The base is at 25 m.

On the east, corals are found only to the south-east; the rest of the platform is largely devoid of suitable hard substrate for coral colonization. The shallowest area harbors large quantities of unusual encrusting forms of *Acropora*. Some soft corals are common. The edge of the near-vertical slope bears many foliose and encrusting corals, with free-living *Fungia*. Patches of corals are common down to nearly 30 m.

The southern platform is similar to the north side in having abundant large coral heads on a gently sloping sandy bottom. *Millepora* spp. and small wave-resilient *Pocillopora* colonies are common on shallow boulders. A similar fauna exists in a knoll-like formation in the south-west. This structure is cut by grooves, probably from erosion. Intermittent patches of foliose and encrusting forms occur in deeper areas.

The west has a dense coral population, especially just below tide level. *Acropora* and *Montipora* predominate, with soft corals in deeper parts. The steep drop-off has a high diversity of encrusting and foliose forms, and a wide range of gorgonians and sea whips. A large sand channel has a wide variety of free-living corals; *Psammocora* and *Fungia* inhabit the base of the wall and some large shelf areas. Some areas support delicate colonies of *Seriatopora*.

Forty-five genera of corals have been reported at Sombrero Island (McManus *et al.*, 1981); *Acropora* colonies of different growth forms are dominant. Other abundant corals are: *Pocillopora* sp., *Montipora* sp., *Porites* sp., and *Pachyseris* sp. Overall coral cover was estimated at about 45%.

**Noteworthy Fauna and Flora** The grass *Themada triandra* covers about 75% of the total area of the island. The fish fauna was studied by McManus *et al.* (1981) and Murdy *et al.* (1981) and 329 fish species have been recorded. The top ten genera of fish in terms of abundance are *Anthias, Pomacentrus, Plectroglyphidodon, Dascyllus, Chromis, Apogon, Thalassoma, Pseudocheilinus, Halichoeres* and *Cirrhilabrus*. The blenny *Andamia pacifica* dominates the rocky shoreline. The invertebrate fauna includes the soft corals *Xenia, Sarcophyton*, tunicates *Polycarpa, Oxycorynia*, bivalves *Lopha* and gastropods, especially the Money Cowrie *Cyprea moneta*. The asteroid *Linckia* is found in shallow areas (MPRDP, 1982b).

**Scientific Importance and Research** Research on the island's coral communities has been carried out primarily in preparation for its establishment as a marine park. McManus *et al.* (1981) and Murdy *et al.* (1981) studied the fish fauna. A study is currently being conducted by the NRMC and BFAR on the effects of tourist activities on coral reef and related fisheries; this involves the assessment of coral damage due to boat anchors and diving activities. White (1986b) included this area in a comparative study of the effectiveness of marine reserves in the management of coral reefs.

**Economic Value and Social Benefits** The area is one of the main fishing grounds for fishermen from the nearby municipalities of Mabini and Tingloy. It is very popular with both local and foreign divers, providing an additional source of income for the local inhabitants and "bankeros" (boat operators); the town of Amilao provides accommodation for tourists.

**Disturbance or Deficiencies** Fishing, both legal and illegal, has been common around the island for a long time. Illegal practices, such as dynamite and muro-ami fishing, have been reported. Commercial fishing (illegal within 7 km from the shoreline) has resulted in a decline in the catch of subsistence fishermen. The increase in aquarium fish collecting may not only decrease fish numbers but also kill other organisms through the illegal practice of using sodium cyanide or other chemicals. The increase in the number of visiting tourists has caused further deterioration through anchor damage, careless divers, spearfishing and coral collection (MPRDP, 1981). However, the actual extent of destruction has yet to be established.

**Legal Protection** Sombrero Island was declared a Marine Reserve and Tourist Zone under Proclamation 1801 but has never been implemented as such.

**Management** The area has been proposed as a Marine Park. The Philippine Tourism Authority (PTA) has been charged with implementing guidelines for the management of tourist activities and there has been some management through the local resorts. Resort owners may brief SCUBA divers and tourists on the existing regulations when visiting Sombrero Island. Recreational activities such as SCUBA diving, swimming, snorkelling, underwater photography, and island picnics are allowed. Fishing in any form, including spearfishing, and collection of marine organisms, is prohibited around the island.

**Recommendations** Recommendations detailed in a management scheme drawn up by the Marine Park Task Force of NRMC cover legislation, sustainable resource use, survey and research methods, zoning, public education, and community participation. It is recommended that enforcement of regulations within the Reserve be delegated to resort owners and employees with the help of the NRMC staff. The Mayors of Tingloy, Mabini and other communities could be enlisted to implement the marine park scheme among their communities. Co-operation among interested parties is needed to create the firm base necessary for proper management (White, 1984).

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## SUMILON ISLAND MARINE RESERVE AND FISH SANCTUARY

**Geographical Location** In Cebu Strait, about 2 km off the southern tip of Cebu Island, Central Philippines, some 17 km north-east of Dumaguete City, Negros Island; 9°21'N, 123°23'E.

**Area, Depth, Altitude** 23 ha in area and 28.4 m at the highest point. The total reef area to 40 m depth is about 50 ha.

**Land Tenure** Municipal Government of Oslob, Cebu. Terrestrial area privately owned but some areas leased by Silliman University.

**Physical Features** Sumilon is a low island of uplifted volcanic basement with a land surface of coralline limestone rock, a thin layer of topsoil, some small hardwood stands, and beach vegetation. It is surrounded by 3-5 m high cliffs on all sides except the north-eastern shore, where a narrow carbonate sand beach and beach rock line the shore and behind which lies a small mangrove lagoon. Beyond the lagoon are 20 m-high limestone cliffs. On the south end there is an abandoned Spanish tower built during the 18th century, with a modern, non-functioning lighthouse next to it

(White *et al.*, 1984). A fringing reef surrounds the island. A shifting sandbar occurs on the north-west corner of the island, adjacent to a small seagrass patch, and is exposed at medium and low tides (White, 1984).

Sumilon is exposed to both the north-east and south-west monsoons. The north-east monsoon, from October to April, often creates choppy sea conditions on the north-east side of the island. The west side receives occasional strong waves from the more erratic south-west winds from May to September. The pronounced drop-off on the west side is probably due to currents around the north and south ends and the original topography of uplifted limestone rock. Currents generally flow in a westerly direction around the island, and the west side is normally free of strong currents. Water visibility at Sumilon varies from 15 to 30 m and water temperature from 27 to 30°C (White, 1984).

**Reef Structure and Corals** The reef crest on the west is separated from the shore by a relatively shallow reef flat (2-3 m deep) approximately 50 m wide. The reef flat does not incline markedly from the shore to the crest and has a high cover of bare sand and rubble interspersed with large areas of living hard coral. The reef crest and reef slope are consolidated limestone with a relatively high cover of soft and hard corals. The crest is about 2-3 m deep. The angle of the slope is about 45-55° to 9 m depth, then drops away at 70-90° between 9 and 14 m depth. Large, overhanging ledges ingressing into the slope for distances of 1 to 3 m are common between 9 and 14 m. The dominant species on the west are *Acropora bruggemanni, A. prominens, Montipora prolifera, Millepora dichotoma, M. platyphyllia,* and *Heliopora coerulea*. *Porites* spp. and *Seriatopora* spp. are also common (Auberson, 1982; Russ, 1984; White *et al.*, 1984).

The reef crest on the east is separated from the shore by a deep (2-8 m) reef flat approximately 100-125 m wide. The reef flat slopes gradually over this distance and has a high percentage cover of sand and rubble, interspersed with living hard and soft corals. The reef crest is 6-8 m deep and this and the reef slope are covered with sand and only a moderate cover of living and soft corals. The angle of the slope is generally shallow (40-45°), but steeper than the northern face (60-70°) (Russ, 1984).

Most of the western reef was damaged by dynamite fishing before the central section was declared a Marine Reserve in 1974. A recent survey (White *et al.*, 1984) shows a marked difference between hard coral cover on the west (reserve) (45.6%) and on the east (15.9%). Although the western reef crest is rich in coral diversity and has a higher percentage cover, the average overall cover is lower than on the eastern, non-reserve side because of its narrowness. Variations in reef zonation appear responsible for this difference.

**Noteworthy Fauna and Flora** Fish populations, especially in the protected area, are higher than around Apo Island (Negros), Balicasag Island (Bohol), and Bantayan Reef (Dumaguete City, Negros) (Russ, 1984). The northern and southern ends of the island are well known for sea snakes, sharks, turtles, manta rays, and barracudas. Whale sharks *Rhincodon typus* have been spotted in the area (Smith *et al.*, 1982). Black corals and gorgonians are common on the south-east (UPMSC, 1979). The Hawksbill *Eretmochelys imbricata* and the Green Turtle *Chelonia mydas* occur (IUCN, in prep.).

**Scientific Importance and Research** Silliman University at Dumaguete City has been using Sumilon as a focal point for much of its marine research. This has shown that the reefs of Sumilon are important, both scientifically and economically, and should be conserved. White (1986b) discussed Sumilon in a comparative study of the effectiveness of marine reserves in the management of coral reefs. Silliman University sends faculty members, students, and foreign researchers to conduct projects, such as the monitoring of fish populations and of transplanted corals (Alcala *et al.*, 1981; Auberson, 1982). The growth of *Tridacna* clams and some algae are also being studied (White, 1984).

**Economic Value and Social Benefits** Fishermen come from the Cebu coast in small outrigger bancas when the sea is calm and the wind not too strong. Under the reserve legislation, traditional, small-scale artisanal fishing is permitted only to the north, east and south of Sumilon. Much fishing takes place in the early morning and at night. Methods used include hook and line, small gill nets, traps, and hand spears. Shallow diving for molluscs, sea urchins, sea cucumbers and crabs and shrimps occurs. In the early 1980s, the annual fish yield in or near the reef averaged at least 17-20 tons/sq. km/year, more than half of this consisting of caesiodids (Alcala, 1981), but it could be as high as 36 tons/sq.km/year (Alcala, 1984b; Alcala and Gomez, 1985). Russ (1985 and in press) found that the reefs had a significantly higher abundance of fish, species richness and abundance of commercially important species than other comparable areas. The Sumilon Reserve and non-reserve sides are regularly visited by foreign and local SCUBA divers and snorkelers (White, 1984). Firewood is occasionally collected on the island.

**Disturbance or Deficiencies** Corals were destroyed by Typhoon Nitang in September 1984 and have been slow to recover (Alcala, 1985). Destructive fishing methods, such as dynamiting and muro-ami were frequently practised until the Marine Reserve was established. Subsequently, illegal fishing has occurred sporadically, as in well-documented cases of muro-ami fishing in the Fish Sanctuary in 1980. Since November 1984, enforcement of the regulations ceased, and local fishermen and others from further afield have started using destructive as well as traditional fishing methods over the entire reef. Recent observations suggest that populations of important food fish have declined significantly, both inside and outside the reserve (Russ, 1986; Russ and Alcala, in press). Previous studies had shown that eastern reefs had a higher level of damage than western ones, which were protected. Some broken corals were observed on the western drop-off due to careless SCUBA diving activities (Alcala and Gomez, 1985; White *et al.*, 1984).

**Legal Protection** Sumilon Reef was established as a Municipal Marine Reserve in 1974 by the municipality of Oslob, Cebu, with the assistance of Silliman University. In 1980, BFAR Administrative Order No. 128 declared the 750 m reserve area on the west as a Fish Sanctuary.

**Management** From 1974 until 1980 Sumilon was managed by Silliman University in co-operation with the municipal government. A strictly protected marine sanctuary was established on the western side of the island in which fishing and collecting was prohibited. The municipal government authorized the University to regulate fishing and collecting, and the University built two rest houses and a field station and provided a caretaker (until 1984) to monitor fishing activity and enforce the regulations in the reserve area. Monitoring of the reef's resources was carried out by the University. Mooring buoys were placed in the reserve for dive boats. Following change in legislation in 1980, Silliman University and the national police prevented infringement of the regulations by fishermen. Since 1984, following problems with local government, there has been no enforcement of the legislation (White, 1987).

**Recommendations** White (1984 and 1987) discusses reasons for the current failure of the Reserve and provides recommendations for the future management of Sumilon based on experience gained from setting up of the marine park program. They include the need for better communication between implementors of management schemes; education of local fishermen on the significance of the marine reserve; establishment of a management board composed of representatives from involved parties; formation of "core" and "buffer" zones around Sumilon; and closer monitoring of human activities. Recently, there have been indications that the fishermen would be willing to cooperate with Silliman University in the re-establishment of the reserve (Gomez *in litt.*, 12.2.87).

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## TUBBATAHA REEFS PROPOSED MARINE RESERVE

**Geographical Location** The middle of the Southern Sulu Sea, about 110 mi. (177 km) south-east of Puerto Princesa City, Palawan; Jessie Beazley Reef lies 13.5 mi. (22 km) north-west of North Reef; 119°52'E, 8°50'N.

**Area, Depth, Altitude** North Reef: 16 x 4.5 km; 3 ft (1 m) high at North Rock; South Reef: 9.2 x 5.5 km; 6 ft (2 m) high at South Islet; Jessie Beazley Reef: 10 m wide with 1 km diameter reef flat; 6 ft (2 m) at the sand cay.

**Physical Features** The Tubbataha Reef complex is composed of two atolls, North and South Reefs, which are separated by a channel 8 km wide oriented south-west/north-east. Tubbataha is exposed to both the south-west and the north-east monsoons. Rough seas are experienced from July to October and from November to March in the north-east monsoon. Most tourist and fishing activity takes place from March to June when calmer seas prevail (White, 1984).

The larger, oblong-shaped North Reef has a continuous reef platform about 200-500 m wide and completely encloses a sandy lagoon 1-24 m deep. Coral patches and mounds, soft corals and algae are scattered within the lagoon. The reef flats are shallow and emergent in some places at extreme low tides. Steep and often perpendicular walls characterize the seaward face of the reef. North Rock, on the northern part of the larger reef, rises 3 ft (1 m) above water. Currents in this area may be strong (NRMC, 1982; Smith *et al.*, 1982). On the north-east tip of North Atoll there is a coral islet (Bird Islet) 1.5-2 ha in size. On the southern side there is a small cay connected to an islet by a narrow strip of sand emergent at low tide; the islet is surrounded by a seagrass belt 30-50 m wide. South-east Sand Cay is located on the south-east part of the reef, towards the lagoon, and is 2-2.5 ha wide and 1.5-2 m high at mean low water. At the southernmost tip of North Atoll there is a clump of emergent coral outcrops called South Rock, on the south-west side of which a triangular rock is emergent at mid-water marking an anchorage for small ships with 3-5 m draft (NRMC, 1982; Palaganas *et al.*, 1985).

South Atoll is triangular in shape, 5 naut.mi. (9.26 km) long, widest (3 naut. mi., 5.6 km) at the northern end, and lies on a north-south axis. Like North Reef, it consists of a shallow platform enclosing a sandy lagoon with numerous patches of hard and soft corals, and algae. The southern tip of South Reef has a 2-3 ha coral island enclosed by a metre-high concrete escarpment, which has a lighthouse (NRMC, 1982).

Jessie Beazley Reef has a small, 100 m wide sand cay and 1 km diameter shallow reef flat and fringing reef (NRMC, 1982; Smith *et al.*, 1982).

**Reef Structure and Corals** Some distinct physiographic zones may be discerned on the Tubbataha Reefs. The deeper stretches of the steep drop-off show foliose or plate-like forms of *Pachyseris, Leptoseris* and *Montipora* at 20-30 m depth. At 12-20 m depth, massive *Diploastrea, Platygyra* and *Porites* are found. The reef edge is an *Acropora* zone with branching *Montipora, Pocillopora, Porites* and some faviids, and extends to a reef slope of similar composition. The reef flats consist mainly of *A. hyacinthus, Pocillopora, Millepora* and some faviids. *Porites* "microatolls" and branched *Porites* characterize the back-reef areas. Towards the lagoon side there are seagrasses and algae on shallower sandy substrates with some patches of *A. pulchra* and *A. intermedia* in the deeper, silty areas (NRMC, 1982).

A diverse coral assemblage with about 46 coral genera has been recorded; a list is given in Pichon (1977b). Coral cover may reach almost 70-80% on many parts of the reef slope and edge, but decreases towards the algal ridge surge zones, back-reef and lagoon.

**Noteworthy Fauna and Flora** North-east Islet has a colony of Brown Boobies *Sula leucogaster* and some Red-footed Boobies *S. sula*. South Rock (North Reef) has a tern *Sterna* sp. colony. South Islet, once a colony, has a variety of birds including Red-footed Boobies, Brown Boobies, the Common Noddy *Anous stolidus*, the Sooty Tern *S. fuscata* and the Crested Tern *S. bergii*. Marine turtles nest on some beaches, such as South-east Sand Cay and North-east Islet (both on North Reef). These are probably *Chelonia mydas*, as evidenced by turtle tracks, dug up nests and dried carapaces. A very high diversity of fish fauna has been recorded in visual day-time censuses showing at least 40 families with 379 species. Sightings of Black-tip *Carcharinus melanopterus* and White-tip *Triaenovon abesus* Sharks, Manta Rays *Mobula dibolus* and Eagle Rays are common. Tridacnid clams are common and helmet shells *Cassis cornuta* are found in some parts of the lagoon. Sacks of Chambered Nautilus *Nautilus pompilus* collected in the area have been seen. The dominant macroalgae are *Caulerpa urvilliana* and *Turbinaria*, and seagrasses abound in the shallow sand areas. North-east Islet has grasses; only two trees (*Euphorbiaceae*) have been recorded on the atolls (NRMC, 1982).

**Scientific Importance and Research** Extensive surveys of the Tubbataha Reefs were carried out in 1982 by the Marine Parks Survey team with researchers from NRMC, BFAR and UPMSC. A report with a comprehensive description of ten transect stations and visual observations of the seaward reefs margin's topographic features and inner lagoon habitats was produced (NRMC, 1982). White (1984) studied about five sites on Tubbataha (including Jessie Beazley) and discussed this area in a comparative study of the effectiveness of marine reserves in coral reef management (White, 1986b).

**Economic Value and Social Benefits** The fishery potential has not been assessed but White (1984) suggests that, based on casual observations of the reef standing crop, it may be 30-40% higher than that of Sumilon Island. A wide range of fishing activities are carried out around the reefs (NRMC, 1982; White, 1984), including commercial trawling for tuna, spearfishing and offshore long-lining, aquarium fish collection and general reef gleaning nearshore.

More recently, Tubbataha has become one of the top SCUBA diving destinations in the Philippines. Although the reefs are not easily accessible, they are visited by some dive boats, usually between April and June, and dive tours operate out of Puerto Princesa. Diving may continue until the end of the south-west monsoon but is limited after June. Snorkelling is possible around the stern of a wrecked log carrier, the *Delsan*, but care is necessary because of the relatively strong currents (Smith *et al.*, 1982; White, 1984).

**Disturbance or Deficiencies** Although Tubbataha has remained relatively pristine due to its inaccessibility and its isolation from population centres, it has begun to experience increasing disturbance. White (1984) reports blast fishing, large-scale collecting of sea turtle eggs, killing of sea turtles, collecting of seabird eggs, molesting of seabirds, spearfishing, and aquarium fish collecting. It was reported that at one time over 20 tons of tridacnid clams were gathered in a three-month summer period. Precious shells are also collected. Dive boat anchor damage is not considered a problem but pirates may have caused some damage.

**Legal Protection** None, apart from national legislation.

**Management** Although there is a national ban on the collection of turtles and turtle eggs, and blastfishing is illegal, there is no enforcement in this remote area.

**Recommendations** It is considered important that these reefs be regulated and established as a marine park or reserve. A resource management plan is being considered (Palangas *et al.*, 1985). White (1984) gives a comprehensive summary of possible management strategies for the Tubbataha Reef complex. These include: (a) recommending Tubbataha Reefs as an ASEAN Heritage site for international protection and management support; (b) general closure of certain areas to all exploitative activities; (c) completion of a management plan based on the Marine Parks Survey trip in 1982; (d) designation of prime tourist locations and scientific research areas and the placing of appropriate mooring buoys; (e) enforcement of all current laws regulating destructive activities; (f) prohibition of access to bird and turtle nesting areas; (g) prohibition of dumping of garbage in the area; (h) a communication scheme with all parties concerned (e.g. fishing companies, government, etc.) for information exchange, management, monitoring and co-ordination.

# QATAR

## INTRODUCTION

### General Description

Qatar is a peninsular state some 200 km long which projects northwards from the Arabian Peninsula into the Gulf, and is centred at about 25°N, 51°E. Waters around the country are shallow which presents major constraints on reef development. The west of the country borders the Gulf of Salwah where salinities are double that of oceanic water and coral reefs are absent. On the northern and eastern (Trucial Coast) coasts, salinities are less elevated and there is extensive coral growth. Temperatures may fluctuate beyond the tolerance limits of corals. In 1964 air temperatures fell to 0.5°C and sea surface temperatures in Ad Dawhah (Doha) Bay fell to 4°C as a result of an unusually cold Shamal (cold front with strong northerly winds) (Shinn, 1976). At 1 m from the bottom in about 18 m depth, 80 km from the coast, water temperature was 14.1°C, the normal seasonal minimum along this part of the coast being 16°C (Kinsman, 1964). The regional current direction is from the Saudi Arabian coast and currents flow around the northern point of Qatar and down the east coast. A study of the chemical characteristics of waters in reef areas has been carried out (Emara *et al.*, 1985).

Coral reefs are shallow and of low diversity but are well developed along the east coast. They are the central part of a long and broad line of reefs which extend from Bahrain, down the east coast of Qatar and along the coast of the United Arab Emirates. Shinn (1976) examined several transects leading out from the north and east coasts which crossed extensive reef areas consisting of many kilometres of *Acropora* thickets with some *Porites* and brain corals. The *Acropora* died after the 1964 Shamal, presumably owing to the cold temperature and not to the strong seas, since little physical damage was seen. Over the next 18 months, recovery was steady and by 1966, *Acropora* was again abundant, with colonies ranging from a few cm to 20 cm in height. Observations in 1968 suggested that the reef had completely recovered. Recolonization of the reefs was not from surviving fragments of the initial population of *Acropora* but from planulae originating up-current of the reefs, in Bahrain and the Saudi Arabian islands (Shinn, 1976). Eight species of coral have been identified, *Acropora* sp. and *Platygyra* sp. being the most common (Emara *et al.*, 1985). *Montipora* sp. and *Pavona* sp. occur along the northern part of the coast and *Porites* sp. in the south. *Favia* sp. occurs in the north-east, east of Halul Island. *Psammocora* sp. is found rarely.

The island of Shara'iwah (Sharaawh) has nesting populations of Hawksbill Turtles *Eretmochelys imbricata*; hatchlings are seen in early July but nesting numbers are reportedly very low (Ross and Barwani, 1981). Gallagher *et al.* (1984) describe the status of breeding colonies of seabirds from several localities around the coast of Qatar and on its islands. These include at least four species of terns *Sterna* spp. and occasionally the Socotra Cormorant *Phalacrocorax nigrogularis*.

### Reef Resources

In the late 1970s the shrimp fishery underwent a decline. As a result of this, the Fisheries Department of Qatar prohibited shrimp fishing during the growth period of February to June each year, and shrimp catches subsequently were restored (UNEP, 1984). There is an artisanal fishery (Morgan, 1985) but it is not known to what extent this is dependent on the reefs.

### Disturbances and Deficiencies

Pollution from crude oil and flotsam and jetsam affects many beaches and coastal areas. Raw sewage is discharged into the sea at Halul Island. Shipping causes oil pollution, particularly near Ad Dawhah port (Environmental Resources Ltd, 1986).

### Legislation and Management

Qatar has ratified the International Convention for the Prevention of Pollution of the Sea by Oil and is considering ratifying the MARPOL Convention. An Environment Protection Committee was established under Law 4 of 1981, but is not yet fully active. Law 4 of 1985 covers protection and utilization of Living Sea Resources (Environmental Resources Ltd, 1986).

### Recommendations

Studies of flora and fauna and related topics, including human impact on the environment, are conducted by the University of Qatar. A sea-going oceanographic research vessel has been provided with help from Unesco (Gallagher *et al.*, 1984). A national marine and coastal zone development and protection plan has been proposed to protect the marine resources. In particular, marine waste disposal, marine mining and transportation, coastal land use and living marine resources should be addressed (UNEP, 1984). Recommendations concerning pollution are given in Environmental Resources Ltd (1986).

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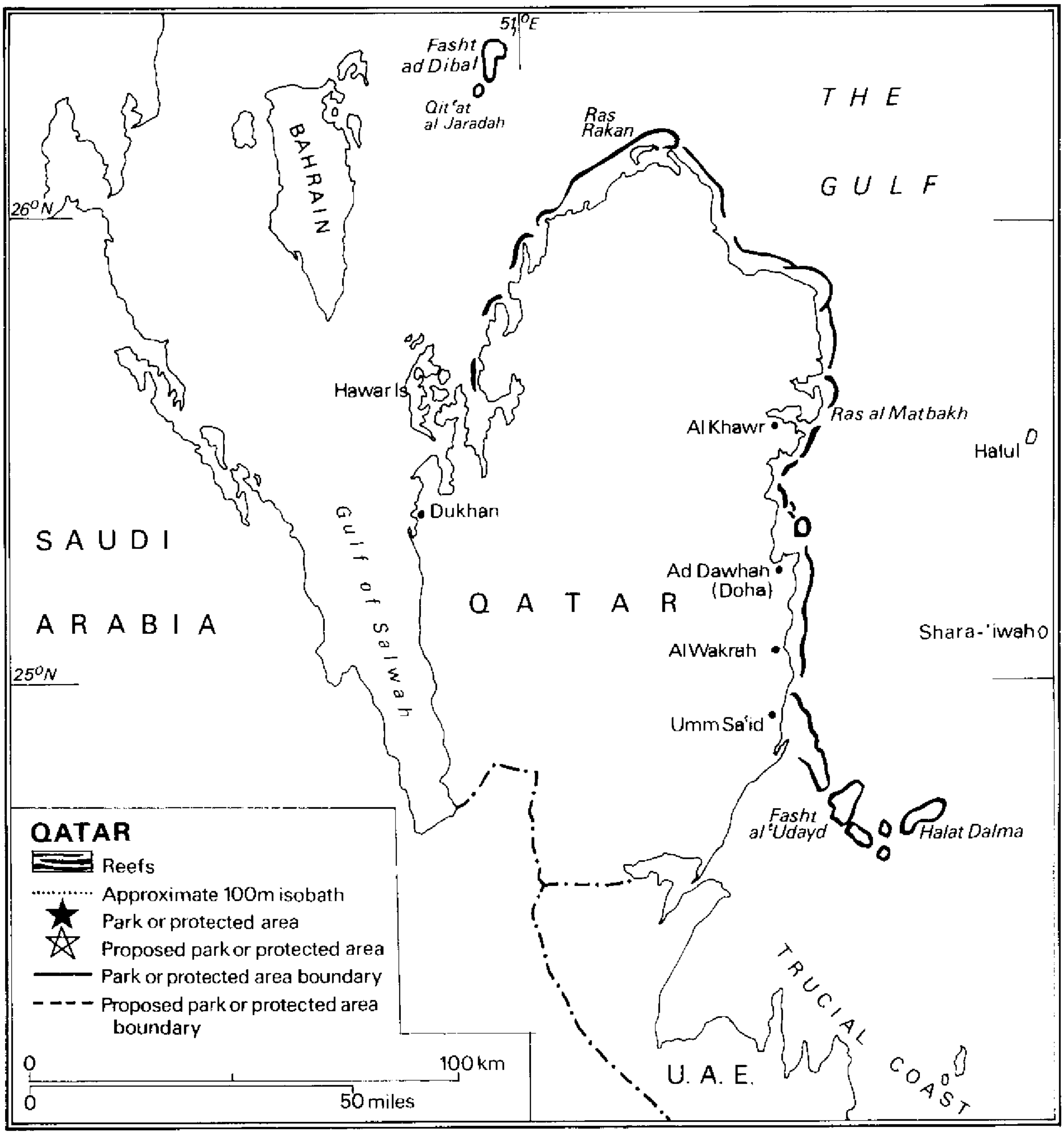


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# REUNION

## INTRODUCTION

### General Description

Réunion (21°7'S, 53°32'E) is the most south-westerly of the Mascarene Islands and is situated about 800 km east of Madagascar. It is the youngest island in this group, is still active volcanically and has the highest peak (3069 m) in the Indian Ocean. Its youth and the narrow, insular shelf are presumed to at least partially explain the relative lack of reef development found here compared with the other Mascarene Islands. The island dependencies of Réunion are located over a wide area of the south-west Indian Ocean and Mozambique Channel: Tromelin to the north of Réunion; the atolls Europa and Bassas de India in the Mozambique Channel; Juan de Nova off the west coast of Madagascar; and the Iles Glorieuses to the north of the Mozambique channel off the north-west coast of Madagascar.

Réunion lies within the influence of the South Equatorial Current, and is subjected to the south-east trade winds which generate waves principally on the south-east. There is a heavy swell of distant, austral origin and tropical cyclones develop during the austral summer. Tides are semi-diurnal, and their maximum range is less than 1 m. Water clarity is generally very high, and surface water temperature has a seasonal range of 21.5-27°C. The geological origins of the reefs are described by Montaggioni (1976).

There are no reefs on the north, east or south-east coasts of Réunion but 10-12 km of fringing reef are found on the south-west coast stretching intermittently from Cap la Houssaye to Grand Bois. It is described by Bouchon (1981), Faure (1975, 1976, 1977 and 1982), Montaggioni and Faure (1980) and Pichon (1971). Harmelin-Vivien and Pétron (1981) provide a popular account. The reef at St Pierre is described by Faure and Montaggioni (1970) and briefly by Harmelin-Vivien (1976). The St Gilles reefs are described in a separate account.

There is generally a reef flat 150-200 m wide, separated from the shore by a lagoon or channel about 2-3 m deep and 300 m wide (Pichon, 1971). There is no algal ridge, except along a section of the reef at St Pierre (Bouchon, 1981), and no boulder zone on the reef flat, although a few large blocks may occur. As a result, there is no clear outer reef flat zone supporting seagrasses. Unlike other Mascarene reefs, this zone supports algae, principally the browns *Turbinaria trialata* and *Sargassum densifolium*. At the shoreward edge of the reef flat, corals are scarce or absent and calcareous red algae are common, providing some cementation for the rubble (Pichon, 1971). Shorewards of this, there is an area of important secondary coral growth where a rich diversity of species provides almost total cover which declines towards shore. In some areas the back-reef slope supports microatolls and has increased cover, especially of *Acropora*. The slope then grades indistinctly into the very shallow lagoon floor which is exceptionally poor in life, being composed of mixed coral with basaltic gravel and sand. Seagrasses are not common, which is attributed to a lack of organic matter and terrigenous material, but they are found in isolated patches such as at St Gilles. The seaward reef slope drops to a bed of "free nodules", composed of calcareous algae and encrusting foraminifera, at about 30 m. Coral cover on the slope may exceed 50%. The uppermost parts of the slope to about 20 m depth exhibit a spur and groove configuration of corals with some calcareous red algae.

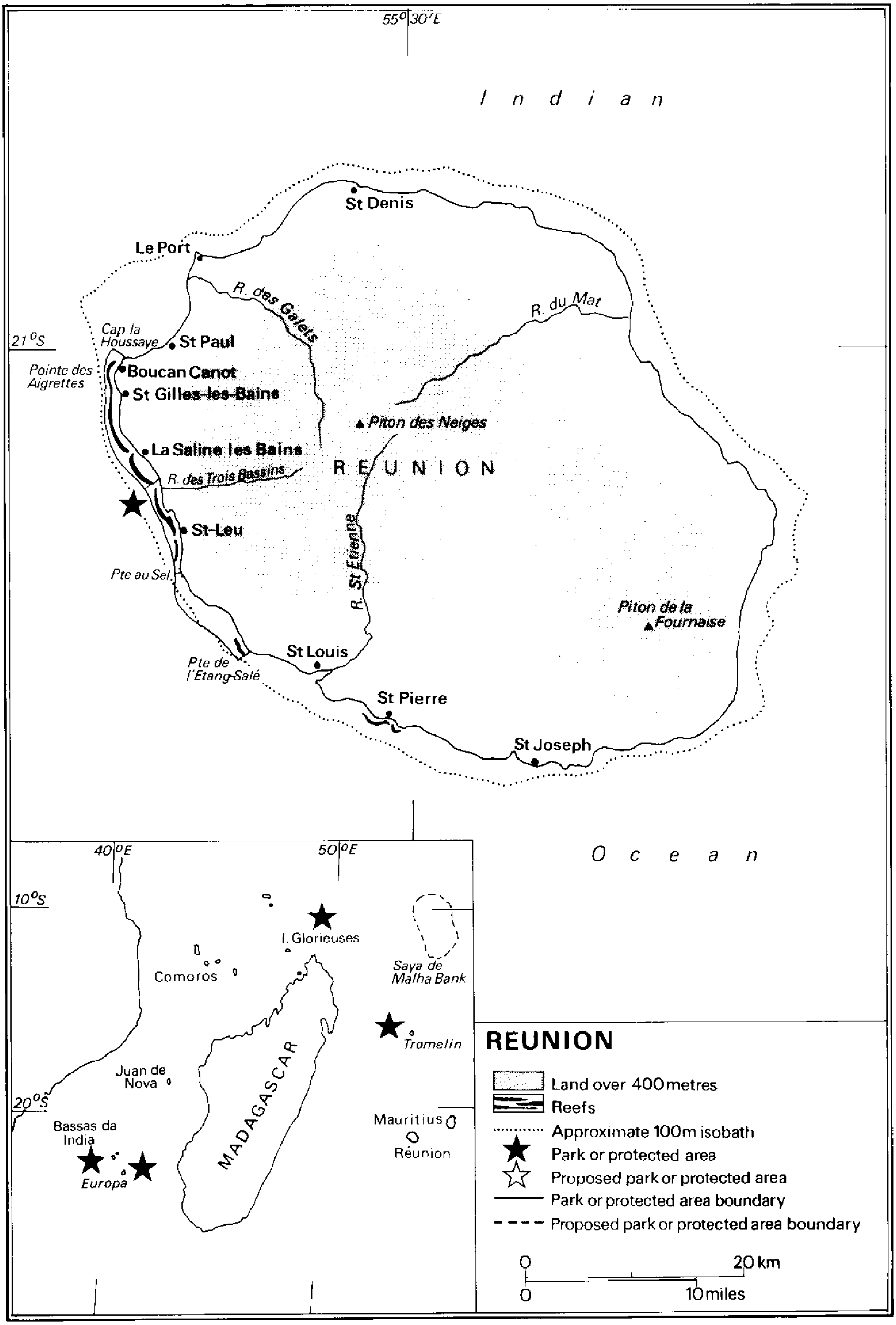
Newer, steep volcanic sublittoral surfaces support numerous coral colonies which do not show zonation, and are not abundant enough to be considered reefs. Pichon (1971) suggests that they may be proto-reefs which could eventually develop further. Although the reefs themselves are few, Réunion has a total of 120 species of coral in 42 genera (Bouchon, 1981), including *Horastrea*, which has otherwise been recorded only from Madagascar and Mozambique.

Tromelin, Juan de Nova, Europa, Bassas de India and Iles Glorieuses are coralline islands or atolls (*see separate accounts*). Delepine *et al.* (1976) describe the ecology of Europa, Tromelin and Iles Glorieuses in relation to climatic factors. The Saya de Malha Bank lies well to the north of the Mascarenes (8°15'-8°12'S, 59°20'-62°20'E) and consists of three separate banks (Caput in the north, Corpus, and Cervix in the south) which are covered by sandy areas separated by coral masses. Green algae covers large areas (Lebeau and Cueff, 1976). Twelve scleractinian coral genera have been reported from the Bank (Stoddart, 1984).

Harmelin-Vivien (1976) describes the reef fish fauna; Gravier-Bonnet (1985) describes hydroids from the fringing reefs. The Réunion dependencies, Europa and Tromelin in particular, support important Green Turtle *Chelonia mydas* populations, amongst the largest in the western Indian Ocean. Hatchlings taken from Europa and Tromelin have provided the basis of a turtle "ranch" (Bonnet, 1985; Hughes, 1981; Le Gall and Fesquest, 1985). Feare (1984) lists thirteen species of seabird known to breed in the Mascarene Islands.

### Reef Resources

The small area of continental shelf and reef and the scarcity of harbours limits the fishing industry. There is an artisanal fishery of about 450 fishermen and 314 boats, line fishing and spearfishing being the principal methods used on account of the submarine topography. About 600-700 tonnes are taken annually, the principal fishing areas being on the fringing reefs off Saint Gilles and La Saline and on those off Saint Leu and Saint Pierre. A significant harvest is also taken by gleaning on the reef flat at low tide. Two species of mollusc, *Turbo argyrostomus* and *T. setosus*, are collected in small numbers (5-10 tonnes a year) on the reef front for use as food rather than for their shells as in other countries. A detailed description of the fishing industry in these areas is given by Robert (1977). There are also some 800 spearfishermen (Anon., 1980a). An I.S.T.P.M. (Institut Scientifique et Technique des Pêches Maritimes) laboratory on Réunion, established initially to study incidents of ciguatera, carries out research on fishery stocks on Saya de Malha, coastal artisanal fisheries and industrial fisheries (Frontier, 1978). The Saya de Malha


55°30'E
Indian Ocean
St Denis
Le Port
R. des Galets
R. du Mat
21°S
Cap la Houssaye
St Paul
Pointe des Aigrettes
Boucan Canot
St Gilles-les-Bains
Piton des Neiges
La Saline les Bains
R. des Trois Bassins
REUNION
St-Leu
R. St Etienne
Pte au Sel
Piton de la Fournaise
St Louis
Pte de l'Etang-Salé
St Pierre
St Joseph
40°E
50°E
10°S
I. Glorieuses
Comoros
Saya de Malha Bank
Tromelin
MADAGASCAR
Juan de Nova
20°S
Bassas da India
Europa
Mauritius
Réunion
REUNION
Land over 400 metres
Reefs
Approximate 100m isobath
Park or protected area
Proposed park or protected area
Park or protected area boundary
Proposed park or protected area boundary
0 20 km
0 10 miles

Bank, particularly the two northern banks (Caput and Corpus) is a major fishing area, particularly for Lethrinidae (Lebeau and Cueff, 1976). Problems associated with ciguatera are described by Lebeau and Cornu (1976).

Tourism is an important element of the economy in Réunion and is described in Anon. (1980a). The most popular beaches are on the west and south coasts, particularly in the La Saline-St Gilles area. Malick (1976) suggests that the island dependencies also have considerable potential for tourism.

**Disturbances and Deficiencies**

The reefs of Réunion have suffered greatly from recent high coral mortalities, the cause of which is not yet fully understood (Guillaume *et al.*, 1983) but may be associated with the sea-warming effects of the 1982-1983 El Niño (Glynn, 1984). Up to 80% of the *Acropora* on the reef flats is reported to have died in some areas and algae now provide 80-90% of the live cover. On the reef slopes, coral bleaching has been found down to 20 m and *Porites* colonies have been particularly badly affected; about 20-50% of the hard and soft coral cover has disappeared to be replaced by algae.

The coast is heavily populated. Chemical pollution, siltation and overcollecting of reef resources have been cited as problems (Gruchet, 1983) and the reefs have deteriorated in several areas such as La Saline and Etang-Salé (Gabrié, 1986). Spearfishing and fishing with dynamite probably causes damage to the reefs. The reefs were once used regularly as a source as lime (Robert, 1977) but there is now only one factory which uses coral sand. However, there is still collection of corals by individuals although it is not known to what extent this causes damage. There have been some reports of localized overfishing of *Turbo* spp. Spiny lobsters and populations of ornamental shells, particularly cowries and helmet shells such as *Cypraecassis rufa*, were already seriously depleted by the 1970s (Robert, 1977). Damage may be caused by the collection of organisms from the reef flat at low tide and through trampling of the coral (Anon., 1980a).

Industrial, agricultural and domestic pollution may be becoming an increasing problem, especially between St Gilles and Boucan Canot. Elevated levels of nitrates, phosphates and organic matter have been recorded in the lagoon (Gabrié, 1986). It has also been suggested that the algal overgrowth may have partly been caused by pollution (Anon., 1982). A discussion of the impact of pollution is given in Faure (1983).

**Legislation and Management**

Réunion comes under French legislation. The Conservatoire de l'Espace Littoral et des Rivages Lacustres was created in 1975 to manage the coastal zone in France and its départements, including Réunion, and plays an important role in appropriating land for protection and management (Anon., 1980b). Management of the coastal zone in Réunion is regulated under "Circulaire du 26 aout 1980, relative à l'utilisation des terraines domaniaux du littoral dans les départements d'outre-mer". The National Park Law 60.708 of 22 July 1960 provides the general framework for establishing national parks and the Loi sur la Protection de la Nature, 10 July 1976 also covers environmental protection. Parks and Reserves are the responsibility of the Office National des Forêts within the Direction Régionale pour la Réunion. Marine environmental affairs are largely discharged by the Ministry of the Environment under directorates for the Prevention of Pollution, Protection of Nature and Water Quality. A multi-disciplinary pollution study is under way with the Institut Scientifique et Technique des Pêche Maritimes. The Association pour les Etude d'Aménagement et d'Urbanisme de la Réunion has produced information booklets and leaflets on the need for reef conservation (Gabrié, 1986).

Fishing is controlled under Décret 78148 of 3.2.78, which covers the EEZ, and Arrêté 2862 of 21.7.76 which prohibits the use of dynamite or poison for fishing and provides a number of other controls over fishing methods such as setting size limits and close seasons for fish and crustaceans (the collection of spiny lobsters is prohibited between 1 January and 31 March) and prohibiting the collection of living corals and molluscs other than mussels. Arrêté 1486 of 1969 also prohibits the collection of coral from the lagoon but permits the extraction of coral sand from the dunes and dead corals from beaches (Anon., 1980a). Spearfishing is prohibited between 1 October and 31 December, at night, within the reserves and for spiny lobster, coral and shells at all times under Arrêté 1904 of 25.5.76. Turtles are protected. Many of these decrees are poorly enforced (Gruchet, 1983).

Under Arrêté 1905 of 25.5.76, the lagoon was declared a fishing reserve and three areas were declared "réserves tournantes" (*see separate account*); each area is closed in succession to fishing except on foot and by line, for a two or three year period:

1. Cap la Houssaye - Ravine Trois Bassins
2. Ravine Trois Bassins - Pte de Bretagne (Pte au Sel)
3. Pte de Bretagne (Pte au Sel) - Pte Etang-Salé

The fishing reserves are administered by the Administration des Affaires Maritimes (Gruchet, 1983) but there is no enforcement (Gruchet *in litt.*, 26.1.87). A "réserve intégral" was established at La Pointe des Chateaux, St Leu, under a decree of 4.9.69 (Harmelin-Vivien and Pétron, 1981), but with the development of the turtle hatchery in this area, the reserve was abandoned (Gabrié *in litt.*, 12.12.86) and the new fishing reserve declared.

The island dependencies of Europa, Bassas de India, Iles Glorieuses and Tromelin (*see separate accounts*) were declared primarily as Réserves Naturelles to include all marine and terrestrial life under Arrêté 13 of 18.11.75. This piece of legislation replaced a decision of 28.7.71 (Gare, 1977; Gruchet, 1983; Harroy, 1972; Malick, 1976) which protected Juan de Nova but not Bassas de India. Due to political confusion (the islands are claimed by Madagascar), the reserves have not been formally designated (Malick, 1976).

**Recommendations**

It has been recommended that there should be two or three large fixed reserves in which only traditional fishing methods would be permitted, rather than the current system of rotating reserves. Improved enforcement of the existing legislation at all levels, as described by Gabrié (1986), is urgently required. Education and public awareness programmes are required. Coastal road building must be controlled. The export of shells should be prohibited and the marine curio trade controlled. Efforts should be made to regulate recreational activities and to attract tourists to the north coast to decrease the pressure on the west coast (Anon., 1980a; Anon., 1982; Gabrié, 1986; Gruchet, 1983). Pollution must be controlled. Gabrié (1986) illustrates a variety of methods for minimising effluent discharge into the lagoon. Aquaculture should be promoted as a source of revenue. Recommendations for coastal zone management are given in Anon. (1980a). Reefs must be zoned for tourism, strict protection, education and other functions and managed appropriately. Some areas of reef, such as at Saint Leu, are still relatively healthy (Gabrié, 1986) and should be given priority for management. Further research is proposed in Anon. (1982).

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## CAP LA HOUSSAYE TO PTE ETANG-SALE RESERVES TOURNANTES

**Geographical Location** South-west coast.

**Area, Depth, Altitude** The fringing reef is about 12 km long; the entire reef area from the beach, through the lagoon or channel, to the reef flat and seaward slope is about 1 km wide; reefs found to 30 m depth. The boundaries of the reserves extend 1 km out to sea.

**Physical Features** Situated on the leeward coast of Réunion, the reef of La Saline is protected from the direct action of the trade winds but is subjected to both a rough, choppy sea, a strong oceanic surge from the south, and occasional strong swell from cyclones. Tides are semi-diurnal with an amplitude of 0.8 m at spring-tides. Tidal movement is often masked by other meteorological effects which pile water onto the reef and channel behind, such that the reef flat rarely dries out. Water clarity is very high, and temperatures range from 22° to 28°C, varying only slightly from the surface to 40 m depth (Bouchon, 1981).

**Reef Structure and Corals** The reef, part of one of the longer stretches of fringing reef in Réunion, was surveyed by Bouchon (1981) at its widest point. On the seaward reef slope, a spur and groove zone extends perpendicularly to the edge of the reef flat for 400 m, to a depth of 20 m. The spurs are of biogenic origin, constructed from both corals and calcareous algae. At 5 m depth the grooves are U-shaped and 5-10 m apart, with an increasing cover of sand and rubble. The relief of these structures disappears progressively with increasing depth.

In depths shallower than 5 m, corals and red algae each have a cover of about 50%. *Millepora platyphylla* is abundant, and among scleractinians, *Acropora* spp. and several faviids are most common. These cover the tops and walls of the spurs, while the floors of the grooves are abraded and largely free of attached biota. From 5 to 20 m depth, coral cover declines steadily from 45% to 30%, although coral diversity increases. Two species of *Pocillopora* are most abundant, followed by *Acropora* spp. and massive *Porites* colonies. Encrusting red algae disappear at 10 m depth, where *A. danai* covers 60% of the substrate.

Below 25 m depth, corals become sparser and smaller, and diversity declines slowly. Below this, typically deep water species appear, covering only 20% of the substrate, but providing the highest diversity of all. *Horastrea indica* is found in deeper areas. This zone grades into a "nodules field", an area where melobesid algae and corals, bryozoans and foraminifera form nodules averaging 100 mm in diameter. These attain ages of 400 to 500 years, and are periodically turned by strong cyclonic surges every 12 to 18 months such that all sides grow slowly. They persist down to at least 65 m depth (Bouchon, 1981).

The reef flat has no algal ridge or boulder zone. Its outer edge has channels cut perpendicularly to the edge, corresponding to the grooves in the spur and groove zone. Behind this, there is 69% coral cover and *Turbinaria mesenterina* is common. The remainder of the substrate is completely covered with calcareous red algae of the genera *Porolithon* and *Peyssonnelia*. Behind this, the corals *A. pharonensis* and *Pavona divaricata* in particular increase in abundance and colony size, forming super-colonies covering tens of square metres, each species occupying about one third of the colonized part of the reef flat. There is little seagrass on the reef flat, although patches of *Syringodium isoetifolium* occur in the northern part. These appear to regress during annual cyclonic storms.

In the channel or lagoon behind the reef flat there is little stable hard substrate and little coral. A few species of corals and several sponges cover 2.5% of the substrate. Corals are more common on the lagoonal side of the reef flat, where their accumulation may be contributing to some growth of the reef flat towards the shore.

**Noteworthy Fauna and Flora** The marine benthic flora of the St Gilles reefs is described by Payri (1985). There are isolated seagrass beds of *Syringodium isoetifoleum*.

**Scientific Importance and Research** Most of the work carried out on the reefs of Réunion has been carried out in this area. Guillaume and Carrio-Schaffhauser (1985) studied the physiology of *Porites lutea*. The "nodule field" on the seaward slope at 20 m and deeper is not unique but appears to be better represented here than at other places from where similar phenomena are reported (Bouchon, 1981).

**Economic Value and Social Benefits** The area is important for artisanal fishermen (Robert, 1977). It is also the centre of the tourist industry, with numerous hotels providing reef-related recreational activities (Anon., 1980a).

**Disturbance or Deficiencies** There has been rapid development and urbanization of the coast in this area which is probably at least partly responsible for the deterioration of the reefs. For example, the sponge *Cliona* now occupies half of the available substrate and out competes corals (Bouchon, 1981). However the reef at St Leu is said to be relatively healthy (Gabrié, 1986).

**Legal Protection** The three reserves were established on 25.5.76 under Arrêté 1905, and are rotating, each zone being closed to fishing, except on foot and by line, for a period of two or three years. The reserves were designated as follows:

1. Cap la Houssaye - Ravine Trois Bassins (closed 1.1.79-31.12.81 under Arrêté 4666 of 17.11.78).
2. Ravine Trois Bassins - Pte de Bretagne (closed 1.1.77-31.12.78 under Arrêté 1905 of 25.5.76.
3. Pte de Bretagne - Pte Etang-Salé (closed 1.1.82 to 31.12.84 under Arrêté 333 of 20.1.82).

It is not known which zone in closed at present.

**Management** The reserves are administered by the Administration des Affaires Maritimes (Gruchet, 1983).

**Recommendations** General recommendations for improved management of the reefs of Réunion are given in the "Introduction" and are particularly relevant to this area which is the most important reef site.

## EUROPA AND BASSAS DE INDIA RESERVES NATURELLES

**Geographical Location** South Mozambique Channel, approximately 1400 km west of Réunion. Europa is at 22°20'S, 40°20'E; Bassas de India is about 100 km north-west of Europa.

**Area, Depth, Altitude** Europa is about 6 km in diameter with a max. alt. of 6 m. Bassas de India has no significant dry land, but the coral area is about 9 mi. (13 km) in diameter.

**Land Tenure** Part of French Republic, administered by Réunion.

**Physical Features** Both atolls are subjected to the Agulhas Current and occasional cyclones, the effects of one cyclone being graphically described by Cousteau and Diolé (1971). Climatological data are given by Delepine *et al.* (1976). Water temperatures are generally above 30°C, and the the south-east trades dominate during the austral winter. Rainfall averages 600 mm a year. Brief details of both islands are given in Bonnet (1986).

Both atolls are said to be in an advanced stage of development. Europa is nearly circular and of volcanic origin, and has an exceptionally shallow lagoon generally less than 1 m deep and fringed with mangroves. A smaller lagoon supports a mixed vegetation. The rim of the atoll is a karst structure (Battistini, 1966) which reflects an older structure. There is extensive exposed coral rock, much of which is pitted, with rubble and sand dunes in the south-west. Further details are given in Delepine *et al.* (1976). Seagrass beds occur in the lagoon and on the north of Europa.

Cousteau and Diolé (1971) and Decary (1937) described Bassas de India as a perfectly shaped atoll, barely emergent at low tide, and therefore supporting no vegetation.

**Reef Structure and Corals** No detailed surveys have been carried out on the reefs, although Battistini (1966) provided a description of the surface features and biota of Europa. Reef flats were about 500 m wide and supported several corals, especially microatolls of *Porites* and *Acropora*. There was a spur and groove structure at the outer edge followed by a steep drop. On several parts of the atoll's outer slope, especially in the north, reef was forming although Battistini (1966) commented that in many areas the reef reflected older reef growth rather than modern construction. Cousteau and Diolé (1971) surveyed the outer slope to over 350 m and reported a profusion of life. Less information is available on Bassas de India. There is a pass into the lagoon and Cousteau and Diolé (1971) reported large expanses of dead coral and bare coral rock. Further details are given in Delepine *et al.* (1976).

**Noteworthy Fauna and Flora** The beaches of Europa are important breeding grounds for Green Turtles *Chelonia mydas*, with several thousand nesting (Hughes, 1981; IUCN/UNEP, 1984; Vergonzanne *et al.*, 1976). Europa supports breeding populations of Brown Boobies *Sula leucogaster* and Sooty Terns *Sterna fuscata* of unknown numbers (Feare, 1984). Reef fish are described by Fourmanoir (1952 and 1963). The lagoon at Europa supports an abundant fish fauna (Malick, 1976) and is fringed with mangroves (Delepine *et al.*, 1976). Vegetation on Europa is described by Decary (1937).

**Scientific Importance and Research** Europa was the subject of an expedition by the Musée National Histoire Naturelle, Paris in 1966 (Battistini, 1966) when detailed studies of the terrestrial biota were made. The isolation of the island makes it a suitable site for further research. There has been a long term project on Green Turtles (Vergonzanne *et al.*, 1976). Scientific work on Bassas de India is minimal.

**Economic Value and Social Benefits** A meteorological station was built in 1950 (Malick, 1976) and there is a runway. Goudeau (1960) briefly described fishing activities on Europa in the late 1950s, Fourmanoir (1952) having described the potential for commercial fisheries on the atoll.

**Disturbance or Deficiencies** Goats were introduced from Madagascar in 1860 and in 1976 there was a population of 200. Cousteau and Diolé (1971) considered that the reefs of both Europa and Bassas de India were deteriorating.

**Legal Protection** The islands were established as Réserves Naturelles 17.7.71 (Harroy, 1972) and formally gazetted under Arrêté 13 of 18.11.75.

**Management** None.

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## ILES GLORIEUSES RESERVE NATURELLE

**Geographical Location** North of the Mozambique Channel 114 mi. off the coast of Madagascar, approximately 1200 km north-west of Réunion; 11°30'S, 47°20'E.

**Area, Depth, Altitude** Grande Glorieuse is 2300 x 1700 m in area; Ile du Lys is considerably smaller; Les Roches Vertes are islets close to Grande Glorieuse. Max. alt. on Grande Glorieuse is 12 m (Battistini and Cremers, 1972).

**Land Tenure** Part of the French Republic, administered by Réunion.

**Physical Features** Most information on this small group of islands comes from Battistini and Cremers (1972), Bonnet (1986) and Stoddart (1967). The group consists of two islands, Grande Glorieuse and Ile du Lys, lying on a large coralline platform, 17 km long and aligned south-west/north-east, the outer slopes of which are extremely steep to at least 1500 m. Grande Glorieuse is oval shaped. On the south and east coast a beach crest or sandy storm ridge, without dunes, reaches up to 10 m above sea-level. The island contains substantial karst-eroded remains of an older reef structure which are dissected by channels and tidal notches. The beach is always sandy, though beachrock extends seaward in three places around the island.

Ile du Lys was formed in a similar manner to Grande Glorieuse and has much guano, mixed with beds of *Halimeda* sand, and seagrasses on the reef flat and shallow reef slope.

The prevailing winds and currents are similar to those described for Nosy Bé (*see section on Madagascar*). There is a mean annual rainfall of 1012 mm which falls mostly between December and March. The prevailing winds are the south-east trades, while during the rainy months winds are mostly from the west and north-west. Other climatological details are given in Delepine *et al.* (1976).

**Reef Structure and Corals** The impression gained from the geological study of Battistini and Cremers (1972) is that the reefs of the Iles Glorieuse have a poor reef biota. On Grande Glorieuse the reef flat extends 300-500 m from shore and is probably an eroded pre-Flandrian structure. The reef slope was not studied but where it was observed in the shallows, the shallow slope beyond a rubble zone had little living coral. *Halimeda* sand is extensive, with isolated coral heads. However, Cousteau and Diolé (1971) suggested that the reef slope is rich and diverse, with profuse coral and fish life.

**Noteworthy Fauna and Flora** The islands' vegetation is decribed by Battistini and Cremers (1972). There are breeding colonies of Brown Noddy *Anous stolidus*, large numbers of Sooty Terns *Sterna fuscata* and possibly Greater Crested Terns *S. bergii*, and Red-tailed Tropicbirds *Phaeton rubricauda* (Feare, 1984). Green *Chelonia mydas* and Hawksbill *Eretmochleys imbricata* Turtles nest on Grande Glorieuse (Vergonzanne *et al.*, 1976). The Coconut Crab *Birgus latro* has been reported from Ile du Lys (Stoddart, 1967).

**Scientific Importance and Research** There is a meteorological station on Grande Glorieuse maintained by the Service Météorologique de la Réunion (Malick, 1976). An expedition from ORSTOM in 1971 studied the cays (Battistini and Cremers, 1972) and there has been a long term project on Green Turtles (Vergonzanne *et al.*, 1976).

**Economic Value and Social Benefits** The islands are visited by diving cruise boats from the Comoros (Anon., 1986).

**Disturbance or Deficiencies** Rats are abundant on Ile du Lys, probably having arrived with the ship, the wreck of which is still visible. There is now only a small colony of terns, inaccessible to rats, on mushroom rocks of *Halimeda* limestone at the western end of the island (Battistini and Cremers, 1972). Grande Glorieuse is largely cleared of natural vegetation but Ile du Lys may still have some woodland (Stoddart, 1967).

**Legal Protection** Declared as a protected area 17.7.71 (Harroy, 1972) and gazetted as a Réserve Naturelle under Arrêté 13 of 18.11.75.

**Management** No information.

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## JUAN DE NOVA

**Geographical Location** Lies in the middle of the Mozambique Channel, 80 mi. (129 km) from coast of Madagascar; 17°03'S, 43°42'E.

**Area, Depth, Altitude** 6 km x 1 km; max. alt. 12 m.

**Land Tenure** Part of the French Republic, administered by Réunion.

**Physical Features** The island is at the centre of a vast platform and is semi-circular in shape. The windward side of the island is scattered with coral blocks and has dunes and rocky prominences to 12 m. The leewardside is sandy and bordered by a dune system (Decary, 1937). The climate is described briefly by Bonnet (1986). Currents around the island may be strong.

**Reef Structure and Corals** The reef flats are emergent at low tide. Fish are abundant in the lagoon (Bonnet, 1986).

**Noteworthy Fauna and Flora** Vegetation is described briefly by Decary (1937). There is a major tern (Laridae) breeding colony between November and April (Bonnet, 1986).

**Scientific Importance and Research** No information.

**Economic Value and Social Benefits** Once inhabited by Seychellois; subsequently mined for phosphate by a French company until 1967. In the 1970s a project to construct a Club Méditerranée was under way. A meteorological station was built in the early 1970s. There is a small runway.

**Disturbance or Deficiencies** No information.

**Legal Protection** Declared as a protected area 17.7.71 (Harroy, 1972) but never gazetted with the other similar dependencies as a Réserve Naturelle.

**Management** No information.

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## TROMELIN RESERVE NATURELLE

**Geographical Location** 15°52'S, 54°25'E; approximately 390 km east of Madagascar, 550 km NNW of Mauritius, 550 km north of Réunion.

**Area, Depth, Altitude** Island is 1750 m x 1000 m; max. alt. 6 m.

**Land Tenure** Part of French Republic, administered by Réunion.

**Physical Features** Most of the annual rainfall of 1045 mm falls in January to April, and the island is dominated in the remaining months by the drier south-east trades. Detailed monthly meteorological data is given in Staub (1970); brief details are given in Bonnet (1986) and Delepine *et al.* (1976).

The pear-shaped island is the top of a fairly symmetrical, conical mountain rising from about 5000 m depth to about 6 m above sea-level. The island profile slopes gently from the highest point in the north-west. Raised reef of the "platin" type in the west changes in the south-east to a belt of coral rocks piled up by the action of heavy swell and trade wind generated waves. On the lee side there are sand dunes and sandy beaches. Reefs occur all round the island, with a pass to the shoreline in the north-west. The reef flats are about 150 m wide.

**Reef Structure and Corals** A brief description of the reefs is given in Bouchon and Faure (1979). Staub (1970) suggests that the steepness of the reef slopes may mean that the reef biota are not richly varied, but there are no data to support this. Fourteen scleractinian genera have been recorded (Stoddart, 1984).

**Noteworthy Fauna and Flora** The Green Turtle *Chelonia mydas* is abundant with several thousand nesting. Hawksbill Turtles *Eretmochelys imbricata* visit the island rarely (Bonnet *et al.*, 1985; Hughes, 1981; Luxmoore pers. comm., Jan. 1987; Vergonzanne *et al.*, 1976). Staub (1970) carried out a survey of the birds and vegetation. The island supports breeding colonies of Red-footed Boobies *Sula sula rubripes* and Blue-faced Boobies *S. dactylatra*, Greater Frigatebirds *Fregata minor*, Lesser Frigatebirds *F. ariel* and White Terns *Gygis alba* (Feare, 1984). Vegetation is sparse and consists mainly of low bushes, *Tournefortia argentia* (Luxmoore pers. comm., Jan. 1987).

**Scientific Importance and Research** The island has a meteorological station which is important due to the fact that southern Indian Ocean cyclones often assume their southerly track in this general region. There has been a long-term project on Green Turtles (Vergonzanne *et al.*, 1976).

**Economic Value and Social Benefits** The island is unpopulated except for the few metereological personnel. There is an airstrip (Luxmoore pers. comm., Jan. 1987; Malick, 1976).

**Disturbance or Deficiencies** Threats to the reefs are probably minimal.

**Legal Protection** The major turtle nesting beaches have been declared reserves (IUCN/UNEP, 1984). Declared a protected area, 17.7.71 (Harroy, 1972) and gazetted as a Réserve Naturelle under Arrêté 13 of 18.11.75.

**Management** No information.

## INTRODUCTION

### General Description

Saudi Arabia is bounded by two semi-enclosed seas: the Gulf to the north-east, and the Red Sea to the west, with the north-western corner of the country adjoining the Gulf of Aqaba.

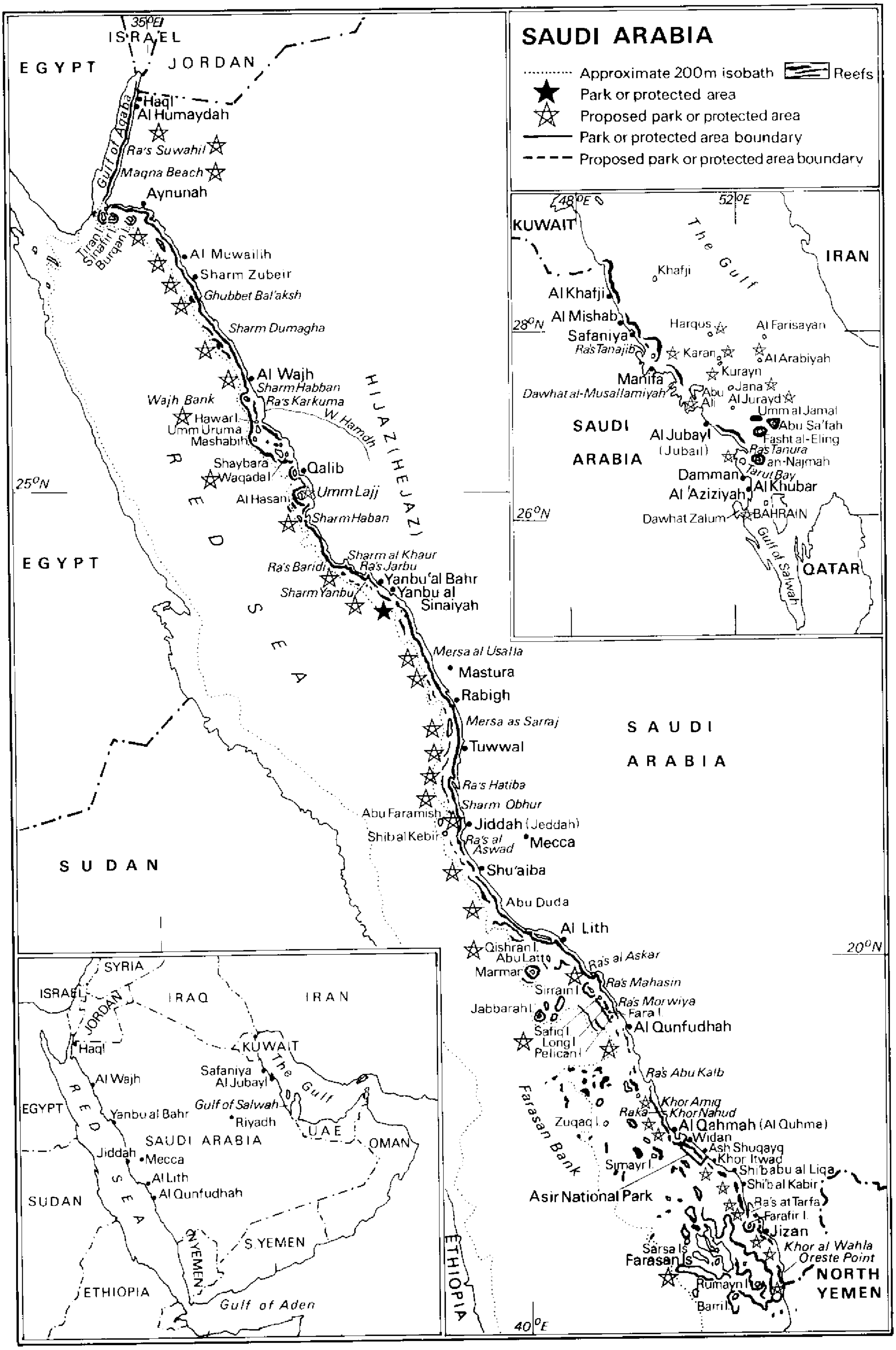
The Gulf coast is characterized by a coastal zone which in many places slopes imperceptibly into the sublittoral, so that vast intertidal and shallow areas exist. Some areas have beach rock, but soft substrate is more usual. The Red Sea coast in contrast, has steep drop-offs to considerable depths and extensive fringing reefs. The continental shelf extends off shore for distances varying from less than 1 km in the Gulf of Aqaba to over 100 km south of Jiddah (Jeddah) on the Farasan Bank. Raised fossil reefs and beaches line the northern half, while further south, mangroves and other soft substrate communities increase in abundance as the coast becomes shallower, and water clarity is much reduced and sedimentation increases. About 1840 km of the Red Sea, or 79% of its eastern shore, lies within Saudi Arabia (FAO, 1981).

Both seas have salinities and temperatures which are greater than the open ocean. The Gulf shows the greatest extremes and the greatest seasonal variation in temperature. The strong prevailing northerly winds create a southerly swell and a south-easterly flowing current along the south coast. The north and north-west sides of the offshore islands are noticeably more exposed. Water temperatures range from 15 to 33°C but greater extremes are experienced in the winter (10°C) and summer (40°C). High evaporation rates, combined with limited water exchange through the Strait of Hormuz, create high salinities. Along the north Gulf coast, salinities increase southwards gradually to Ra's Tanura and then more rapidly to Al Khubar (Al Khobar). From the latter, the coast lies within the Gulf of Salwah where salinities reach 60-70 ppt or more and conditions prohibit significant coral growth. In hypersaline embayments, salinities may exceed 200 ppt. Rainfall is very variable (4-330 mm/year). Freshwater run-off is limited to occasional flooding following local storms and local input from agriculture and irrigation. Terrigenous input is negligible. Tides are a mixture of diurnal, semi-diurnal and mixed (IUCN, 1987d).

On the Red Sea coast, there is a general increase in average air temperature from north to south which may influence the distribution of shallow water marine habitats. Seasonal changes in both air and surface water temperature are more marked in the north than the south. Prevailing wind direction and rainfall are determined by Mediterranean low-pressure systems in winter (Siraj, 1984) and the south-west monsoon in the summer (Morcos, 1970). In the north, the prevailing wind direction is north-north-westerly except for occasional southerly winds in the winter. North-westerly winds strike the coast obliquely for much of its length and water conditions may become fairly turbulent in steeply shelving areas, which favours reef growth. Below 20°N, the prevailing wind direction is northerly in summer and south-south- westerly in winter. An intermediate situation exists in the central Red Sea. In the north, most of the limited rainfall occurs in winter. Further south, rainfall is even lower due to the rainfall shadow of the Hijaz (Hejaz)/Asir scarp, but rainfall on the scarp sustains a relatively high ground-water supply to the coastal plain and there are occasional flash floods. No continuously flowing rivers discharge into the Red Sea. Salinities are lower in the Red Sea than in the Gulf and, except in small, enclosed embayments, nowhere too extreme for coral reef development. Salinity increases from 37 ppt in the south to 42 ppt in the north, with higher values in shallow coastal lagoons (Saad and Fahmy, 1984). Tides are oscillatory and semi-diurnal with a mean spring range of 0.5 m mean sea-level; mean sea level is up to 1.0 m higher in winter. In winter, wind-driven surface waters entering the Gulf of Aden proceed north increasing in temperature and salinity and a southernward deeper counter-current flows out through Bab el Mandeb into the Indian Ocean. The summer northerly winds reverse the circulation pattern and establish a southerly flowing surface current of warm high salinity into the Gulf of Aden. Sea surface temperatures increase from north (winter 21°C, summer 26°C) to south (winter 28°C, summer 32°C). A number of papers on the physical features and marine geology of the Red Sea coast of Saudi Arabia can be found in Saad (1984).

Basson *et al.* (1977) provide the most extensive survey of the Saudi Arabian Gulf coast and more recent information, resulting from a 1986 survey, is given in IUCN (1987d). There is little reef development near shore or along the Gulf coast because of high rates of sedimentation due to constant resuspension by tidal currents and unfavourable bathymetry. Further off shore, however, there are hundreds of patch reefs ranging in diameter from a few tens to a few thousands of metres. Numerous patch reefs are found between Ra's al Mish'ab Safaniya and Abu Ali and between Abu Ali and Ra's Tanura. The majority range in size from 2 to 30 ha and have moderately steep reef slopes extending to about 2.5 m (McCain *et al.*, 1984a and b). Coral cover is between 5 and 80% and genera present include *Acropora, Porites, Platygyra, Favia, Favites* and *Stylophora.* A total of 21 species were recorded on patch reefs in the north which were studied in detail by McCain *et al.* (1984b). In general terms, those furthest from shore are the best developed, and about six support permanent islands of sand and coral rock, while a number of others support sand banks which may be awash or submerged at high tides. Macroalgae dominate on many in the summer months but are sparse from July to November (IUCN, 1987d; McCain *et al.*, 1984a and b).

South of Ra's Tanura there are fewer reefs due to increased salinity and probably also to heavier sedimentation. However, several extensive patch reefs have developed in this region, such as an-Najwah (north-east of Damman) and reef corals have also been recorded in the immediate subtidal zone at several coastal sites (IUCN, 1987d). Few reef corals survive salinities greater than 45 ppt although three species (*Porites nodifera, Cyphastrea microphthalma* and *Siderastrea saviguyana*) tolerate 50 ppt (Sheppard, 1985b). One of


SAUDI ARABIA
Approximate 200m isobath
Reefs
Park or protected area
Proposed park or protected area
Park or protected area boundary
Proposed park or protected area boundary
ISRAEL
EGYPT
JORDAN
Haql
Al Humaydah
Ra's Suwahil
Maqna Beach
Gulf of Aqaba
Aynunah
Tiran I.
Sinafir I.
Burqan I.
Al Muwailih
Sharm Zubeir
Ghubbet Bal'aksh
Sharm Dumagha
Al Wajh
Sharm Habban
Ra's Karkuma
Wajh Bank
Hawar I.
Umm Uruma
Mashabih
W. Hamdh
HIJAZ (HEJAZ)
Shaybara
Waqadal
Qalib
Umm Lajj
Al Hasani
Sharm Haban
RED SEA
Sharm al Khaur
Ra's Jarbu
Ra's Baridi
Yanbu'al Bahr
Yanbu al Sinaiyah
Sharm Yanbu
Mersa al Usalla
Mastura
Rabigh
Mersa as Sarraj
Tuwwal
SAUDI ARABIA
Ra's Hatiba
Sharm Obhur
Abu Faramish
Jiddah (Jeddah)
Shib al Kebir
Ra's al Aswad
Mecca
Shu'aiba
SUDAN
Abu Duda
Al Lith
Qishran I.
Abu Latt
Marmar
Ra's al Askar
Ra's Mahasin
Sirrain I.
Ra's Morwiya
Fara I.
Jabbarah I.
Al Qunfudhah
Safiq I.
Long I.
Pelican I.
Ra's Abu Kalb
Farasan Bank
Khor Amiq
Raka
Khor Nahud
Zuqaq I.
Al Qahmah (Al Quhme)
Widan
Ash Shuqayq
Khor Itwad
Sumayr I.
Shi'babu al Liqa
Shi'b al Kabir
Asir National Park
Ra's at Tarfa
Farafir I.
Jizan
Khor al Wahla
Oreste Point
Sarsa Is
Farasan Is
NORTH YEMEN
Rumayn I.
Barril
ETHIOPIA
35°E
25°N
20°N
40°E
KUWAIT
IRAN
Khafji
The Gulf
Al Khafji
Al Mishab
Safaniya
Ra's Tanajib
Harqus
Al Farisayan
Karan
Al Arabiyah
Kurayn
Manifa
Dawhat al-Musallamiyah
Abu Ali
Jana
Al Jurayd
Umm al Jamal
Abu Sa'fah
Fasht al-Eling
Al Jubayl (Jubail)
Ra's Tanura
an-Najmah
Tarut Bay
Damman
Al Khubar
Al 'Aziziyah
Dawhat Zalum
BAHRAIN
Gulf of Salwah
QATAR
48°E
52°E
28°N
26°N
SYRIA
ISRAEL
JORDAN
IRAQ
Haql
Al Wajh
EGYPT
Yanbu al Bahr
Safaniya
Al Jubayl
Gulf of Salwah
Riyadh
UAE
OMAN
SAUDI ARABIA
Jiddah
Mecca
Al Lith
Al Qunfudhah
S. YEMEN
N. YEMEN
Gulf of Aden

the most southerly reefs of the Gulf is in Tarut Bay (26°36'N, 50°8'E) where salinity reaches 55 ppt; it consists of a large stand of *Stylophora* with extensive patches of *Acropora* and *Platygyra*. Other reef areas of the Gulf coast include the Umm al Jamal reef system south of Al Jurayd Island and opposite Al Jubayl (Jubail), the Abu Sa'fah reef system south-east of Umm al Jamal, the Fasht al-Eling system to the west of the latter and an-Najwah reef about 7 km north-east of Port of Damman (Basson *et al.*, 1977).

Fringing reefs are extensive only around the offshore islands and have been studied in some detail at Karan and Jana (*see separate account*). They generally have a slope less steep than that typically found in the Red Sea. A total of 57 species of reef corals from 31 genera have been recorded from the Gulf, mostly from the offshore islands; these represent an impoverished suite of Indo-Pacific species.

In the Red Sea, coral reefs are widespread because of the availability of hard substratum, including the subsiding terraces associated with the rift, and also the small amount of terrigenous input, low turbidity and high water temperatures although seasonal extremes, especially in shallow areas may be detrimental. In general, reef development and coral diversity are greatest in the central section of the coast. Particularly well developed reefs and dense coral growth have been noted in five regions: the Tiran Islands, the Wajh (Wejh) Bank, the area north of Yanbu, the coastline between Obhur and Tuwwal (north of Jiddah) and the outer Farasan Bank (Crossland *et al.*, 1987; IUCN, 1987c).

Four biogeographic subzones have been proposed (IUCN, 1984a and b): 1) the Gulf of Aqaba, characterized by its geographical isolation and the relatively high number of species restricted to or excluded from it; 2) south of this to a point between Yanbu and Jiddah; 3) from this point south 200 km to include the Farasan archipelago, a region with diverse reefs; and 4) an area within the latter zone which covers the coastal region, characterized by limited reef development due to high temperatures and a high sediment-load but with shallow inshore calcareous algal reefs and silt tolerant corals such as *Porites nigrescens* and *Montipora stellata*.

In subzones 1 and 2, extensive well-developed fringing reef occurs from the Gulf of Aqaba down to at least Jiddah, broken only by occasional sharms and embayments. The reefs and lagoon are narrowest in the north, where coastal cliffs and hills are common and the intertidal areas grade quickly into deeper water. Even where the coastal zone is low-lying and sometimes flooded, the fringing reef commonly continues unbroken but separated from the coast by a few hundred metres. The fringing reefs are commonly backed by a reef flat and soft-bottomed lagoon with seagrasses and sporadic coral outcrops. Five distinct coral communities have been recognised in the Gulf of Aqaba and thirteen at Yanbu (*see separate accounts*). Off shore are the major reef areas of the Wajh Bank and extended offshore platforms which support reefs at least as far south as Jiddah (*see separate accounts*).

From Jiddah southwards, inshore reef development and coral diversity both decline in parallel with the decreasingly favourable environmental conditions as the 200 m contour sweeps away from land to include the Farasan Bank and the nearshore environment becomes increasingly shallow. The supralittoral and terrestrial elements of the coastal zone are generally low-lying towards the south and lack raised reef rock features such as wave-eroded cliffs found in the north. Intertidal reef rock features are obscured or veneered by muds and sands unlike in the north, where the intertidal has a well developed inshore reef rock flat and fringing reef. The sandy or silty sublittoral gently deepens off shore while in the north, the fringing reef system is generally edged by deep water. Fringing reefs occupy less than half of the southern 1000 km of coast, the remainder being occupied by mangroves and other muddy habitats. It has been estimated that sabkah (seasonally inundated flats) occur along 71% of the southern part of the coast, moderately good quality mangrove along 28%, moderately good seagrass beds along 30% and moderately good quality reefs along 24% (IUCN, 1985b).

From Jiddah to about 20 km north of Al Lith, the reefs appear to be well developed. South of Al Lith, they tend to alternate with long stretches of mud and mangroves, further south with sand, and south of Ra's Mahasin they occur only intermittently and support few invertebrates and fish. South of Al Qahmah (Al Qurhma) reefs almost completely disappear. Fringing reefs are deeper in the north of this region with coral growth down to 35 m depth. At Shu'aiba coral growth is found to 12 m depth, at Ra's Mahasin to 20 m depth, but further south only to 4-5 m depth. Nearer Jiddah, the reefs get progressively broader, the edges apparently still growing seawards, and range from 25 m in width at Al Lith to 200 m in some areas.

Sheppard (1985b) describes 27 coral reefs between Jiddah and the southern border. Antonius (1984) surveyed 70 sites on the fringing reefs 100 km north and south of Jiddah. Detailed studies were carried out at Tuwwal, 100 km to the north, Shu'aiba, 100 km to the south and at Jiddah Corniche Beach and Sharm Obhur, near Jiddah (*see separate accounts*). The lagoons at Tuwwal and Shu'aiba had reduced coral diversity, but coral cover was almost 100% dominated by *Stylophora pistillata*, the other species being negligible. Islands off the southern coast are described in IUCN (1984a and b).

Subzone 4 is described in detail in IUCN (1984a and 1985b). Four types of fringing reef have been identified. 1). From Al Lith south to Ra's Mahasin and Al Qunfudhah (Al Qunfidhah) the reefs resemble the classic Red Sea reefs of the Jiddah area but are not as well developed, extending to only about 20 m depth. They have well developed reef flats and a gentle terrace dipping to 2-3 m, followed by a steeper drop. Depending on the depth at which soft substrate appears, there may be a more gentle incline again below a steep drop-off. 2). Clear-water fringing reefs have a simplified structure, may extend seaward for 100 m, and have a maximum depth of 5 m. They are always dominated by *Acropora* and pocilloporids. 3). Turbid-water fringing reefs are similar to (2) but are found adjacent to mangroves and are poorly developed, extending only to 5 m; they drop more steeply than (2) and may be dominated by *Porites* and in one case *Galaxea*. 4). Algal reefs are found south of Ash Shuqayq (Shuqaiq); these have only a few corals, the commonest being *Siderastrea savignyana* which is uncommon elsewhere on the Saudi Red Sea coast, and faviids. The reefs consist mainly of calcareous *Porolithon* red algae and are dominated by *Sargassum* with a maximum vertical extent of 3 m. This community is also common in the shallowest parts of the other reef types as well.

Six distinct coral assemblages have been identified on these four different types of reef (IUCN, 1985b; Crossland *et al.*, 1987): 1) a low diversity, high cover assemblage dominated by several species of *Acropora* and *Pocillopora* has the widest range and is found in wave-exposed areas; 2) an assemblage dominated by table *Acropora* and massive *Porites* is found at greater depths than (1); 3) a high diversity assemblage is found in conditions of moderate exposure in the central part of the southern region; 4) an assemblage characterized by an abundance of *Echinopora lamellosa* and *Porites* spp. occurs further south; 5) an assemblage dominated by *Porites* is found on turbid-water reefs and 6) a distinct assemblage is found on algal reefs in the far south (*see above*).

More than 194 species of coral from 70 genera (50 hermatypic genera) have been recorded from the Saudi Red Sea, none of which are endemic (Scheer and Pillai, 1983; IUCN, 1987a). Highest coral diversity is found in the central region; the number of species recorded increases from 30 (although 150 have been recorded (Scheer *in litt.*, 15.12.86)) in the Gulf of Aqaba to more than 150 off Yanbu and then decreases to about 100 near Jiddah, less than 50 near Al Birk and less than ten on the southernmost Saudi inshore reefs (Crossland *et al.*, 1987; Sheppard and Sheppard, 1985). Decreasing coral diversity towards the south may be related to the increasing shallowness of the reefs. Several coral species, soft corals and *Millepora*, all of which are common further north, disappear. Conversely, a few species which are common in the Indian Ocean (such as *Acropora* cf. *nobilis, A. grandis, A. formosa, Porites nigrescens* and *Montipora stellata*) disappear before Jiddah (IUCN 1984a and 1985b; Sheppard, 1984). Coral cover is uniformly good, 30-60% in clear water.

Detailed descriptions of other coastal habitats on the Red Sea coast, especially seagrass beds and mangroves, are given in Crossland *et al.* (1987), IUCN (1984a, 1985b, 1987c and d) and IUCN/UNEP (1985a) and are summarized in IUCN (1987a). There are several major stands of mangrove, mainly south of 26°N, which become increasingly extensive as reef development decreases. A discontinuous and narrow band is also found along many parts of the coast. Further information is given in Price *et al.* (1987). On the Gulf coast, mangroves are restricted to small stands in several parts of Tarut Bay, covering about 4 sq. km. Seagrasses cover about 370 sq. km, in the Gulf or 1.3% of all subtidal biotopes (IUCN, 1987d).

McCain *et al.* (1984b) describe 106 species of fish associated with patch reefs in the Gulf, including a number of commercial importance such as groupers (Serranidae), snappers (Lutjanidae) and porgies (Sparidae). Ormond and Edwards (in press) and Randall (1983) provide a comprehensive survey of Red Sea fish. There are about 450 common reef-associated species, most of which are abundant in the central region. In the south, species which rely on well-developed reefs and are thus found in the north and centre, tend to be rare, such as *Chaetodon trifascialis, Pomacanthus imperator* and *Pygoplites diacanthus*. There is a general trend of decreasing species richness with decreasing latitude among the parrotfish (Scaridae) and surgeonfish (Acanthuridae), a replacement trend among the wrasses and groupers (Serranidae) and an increase in diversity and abundance of snappers (Lutjanidae) and emperors (Lethrinidae) (Crossland *et al.*, 1987; IUCN, 1985b).

Over 180 species of mollusc have been recorded from the Red Sea coast, including a number of endemic cowries (Cypraeidae) and strombids (Strombidae). Invertebrates of the southern Red Sea coast are described in IUCN (1985b). Price (1982b) describes the echinoderm fauna of both coasts, including a number of endemic species. Two species of marine turtle nest on the Saudi Arabian Gulf coast. The Green Turtle *Chelonia mydas* has a nesting population of several hundreds, 80% of which nest on Karan, also the main site for the few nesting Hawksbill Turtles *Eretmochelys imbricata* (Groombridge, 1982). Five sea turtle species occur in the Red Sea; Hawksbills and Greens are the commonest. Dugongs *Dugong dugon* are occasionally recorded along both the Red Sea and Gulf coasts (Crossland *et al.*, 1987; IUCN, 1985b and 1987d). Gallagher *et al.* (1984) and Crossland *et al.* (1987) describe breeding seabird populations, 14 species having been recorded. A comprehensive bibliography of faunal studies carried out on the Gulf coast is given in IUCN (1987d) and summary descriptions of marine and reef-related fauna and flora are available in IUCN (1987a).

A rapidly increasing amount of research is being carried out on the marine environments of Saudi Arabia. Farmer and Docksey (1983) and Rahim (1979) provide comprehensive bibliographies. In recent years, three main organizations have carried out research on the reefs. Behairy (1982) describes the work done at the King Abdulaziz University in Jiddah where the coastal waters and marine communities between Yanbu and Jiddah are being surveyed. IUCN and the Tropical Marine Research Unit (TMRU) have carried out broad scale surveys along the coast for the Meteorology and Environmental Protection Agency (MEPA) (Crossland *et al.*, 1987; IUCN, 1987b and d). Work has also been conducted through the Royal Commission for Al Jubayl and Yanbu (Sheppard and Sheppard, 1985). ARAMCO (Arabian American Oil Company) has supported a number of studies, including a survey of the Gulf coast (Basson *et al.*, 1977), monitoring of the marine environment at Safaniya, Ra's Tanajib and Manifa on the northern Gulf coast, and studies of sand beaches (McCain, 1984a), nearshore soft bottom benthic communities (McCain, 1984b) and reefs and reef fish (McCain *et al.*, 1984a and b). These studies have been carried out in order to monitor the marine environmental effects of the development of new facilities for the production, processing and distribution of oil resources in the Northern Area of the Saudi Gulf coast and to plan appropriate mitigative measures.

**Reef Resources**

In 1980 oil accounted for more than 91% of the state revenue, which previously depended on agriculture, fishing and pearling. Oil revenue has declined to 75% (SAMA, 1984) and there is now an interest in improving other sectors of the economy, particularly fisheries. There is an important artisanal fishery on the Red Sea coast, much of which is reef-based, involving species such as snapper and emperor bream (Crossland *et al.*, 1987;

Oakley, 1984). Considerable fishery research has been carried out in collaboration with the University of North Wales (U.K.), the White Fish Authority (U.K.), FAO and UNEP. Surveys of fishing centres have been made and the marine laboratory at Jiddah, with the Fishery Research Centre (Ministry of Agriculture), is carrying out research into reef fish stocks (Clark and Vanderbilt, 1982; Kholy *et al.*, 1984; Nawwab, 1976; Peacock, 1979; Peacock and Zahrani, 1978; Wray, 1979). More detailed studies have been carried out on the Tuwwal reef fishery as part of the UNDP/FAO project (Kedidi *et al.*, 1984) and the Saudi Fisheries Company is studying fisheries in the Farasan Bank area (Dakkak *et al.*, 1984b). The coastline from Haql to Al Lith, except perhaps the Wajh Bank, is probably fully exploited. The Farasan Bank, once virtually unexploited, is used more but still holds considerable potential. Handlining and gill nets are the traditional fishing methods employed, and new reef sites suitable for handlining are being identified along the Red Sea coast. The fishing industry is discussed in more detail in Crossland *et al.* (1987) and summary descriptions of the fisheries on both the Red Sea and Gulf coasts are given in IUCN (1987a).

Spiny lobster *Panulirus penicillatus* and *P. versicolor* and slipper lobster *Scyllarus* sp. are fished in limited numbers in shallow water reef areas, particularly for the expatriate market (Neve and Al-Aiidy, 1973). The main fishing areas are between Yanbu and Aqaba, especially on the Wajh Bank (Ross Group, 1966), but the artisanal fishery is also very important on the southern Red Sea coast (IUCN, 1985a). The pearling industry was once of major importance, centred on Jizan and in the Farasans, but this has now died out, partly because the Gulf pearls are considered of better quality (Neve and Al-Aiidy, 1973). The molluscs *Tridacna maxima, Strombus tricornis, Lambis truncata, Trochus* sp., and *Octopus* sp. are taken mainly for bait rather than food. *Trochus* was collected in large numbers for export via Sudan for the mother-of-pearl industry but this ceased in the early 1970s; *Pteria* and *Plicatula* shells were also occasionally used. The horny foot of *Strombus* is sold for jewellery and for use as an aphrodisiac. The black coral *Cirripathes anguina* is collected and sold in Mecca for prayer beads and jewellery (Hiscock and Al-Aiidy, 1972).

There is an important artisanal fishery on the Gulf coast which exploits species including the Hamour Grouper *Epinephelus malabaricus/ tauvina*. Little information is available on the artisanal catch although 5000 tonnes were taken in 1977 (Morgan, 1985). Handlining and gill netting are the main fishery methods. Artisanal and industrial fisheries along this coast are described by IUCN (1987d).

Foreign tourism is not permitted in Saudi Arabia. However, local recreational use of both the Red Sea and Gulf reefs is increasing rapidly. Along much of the Red Sea coast, the lagoon of the fringing reefs form a natural shallow pool which is very popular with the non-swimming public, particularly near cities (Antonius, 1984).

## Disturbances and Deficiencies

Much of the Red Sea coastline is almost unknown to western biologists and is virtually pristine. The Crown-of-Thorns starfish *Acanthaster planci* has been recorded but in very low numbers (Crossland *et al.*, 1987; IUCN, 1985b). However, certain coastal areas are being dramatically altered by industrial and urban development and extensive coastal development, landfilling and coastal engineering (IUCN, 1987b). The construction of coast roads, jetties and harbours may have a noticeable impact through sedimentation, either from infill material entering the sea or through alteration of the water circulation. In addition to the newly developed Jiddah and Yanbu regions (*see separate accounts*), there is a new port at Tuwwal to the north of Jiddah, and at Rabigh the sharm is being developed as a new refinery complex. Some effects of sewage discharge, chemical pollutants and oil are noticeable particularly at Jiddah, although the regulatory measures for discharge introduced by MEPA should have reduced the potential for this type of impact (Crossland *et al.*, 1987). Several papers on the potential threat and existing impact of pollution on reefs of the Red Sea coast are given in Saad (1984). At present there is less evidence of direct impact to the reefs on the southern coast, which is relatively undeveloped and sparsely populated (IUCN, 1985a).

The Gulf coast is being developed equally fast and the proliferation of coastal highways, urban conurbations, industrial plants and oil and petrochemical industries is a major threat to the marine environment (IUCN, 1982c and 1987d). Areas particularly vulnerable to industrial development include Tarut Bay and the region south to Al Khubar, including Damman, which are threatened by coastal infilling, dredging, altered water circulation from man made structures, removal of coastal vegetation, pollution and overfishing. Rubbish is dumped between Al Khubar and Damman and in some areas extends 50 m seawards. There is also much landfilling, particularly at Tarut Bay and in the Al Jubayl/Abu Ali area. High heavy metal concentrations from industrial waste have been found in Tarut Bay (IUCN, 1982c) and the impact of an oil spill in this area is described by Spooner (1970). At Safaniya the largest ARAMCO marine facility serving the world's largest offshore oilfields has been built and there is another at Abu Ali. A number of studies have been carried out to determine the effects of these activities including Menzies *et al.* (1975), Price (1983), Saudi Arabian Tetra Tech (1982) and Wennink and Nelson Smith (1977).

Overfishing is not generally considered a problem at present in the artisanal or commercial fisheries, although the Hamour Grouper fishery on the Gulf coast may be exploited at or in excess of optimal levels (Morgan, 1985). In some areas excessive collection and exploitation of reef invertebrates (corals, molluscs, urchins, octopus) appears to be uncontrolled and damaging, as along the 60 km stretch of coast north of Jiddah, particularly at Sharm Obhur. This is largely due to recreational activities of expatriate labourers (Hiscock and Al-Aiidy, 1972). Studies by Antonius (1984) and Bodoy (1984) have shown that recreational activities have a serious impact. Compared with undisturbed reefs at Tuwwal and Shu'aiba (100 km north and south of Jiddah respectively), the lagoons at Jiddah and Obhur had no corals, apart from occasional small or damaged colonies, and no Giant Clams *T. maxima*. The lack of the former is considered to be due to trampling, the latter to overexploitation. Recreational use of the Gulf coast has resulted in littering between Dawhat Zalum (Half Moon Bay), Al 'Aziziyah

(Sunset Beach), Al Khubar, Khafji, Al Jubayl and Ra's Tanura (IUCN, 1982b).

**Legislation and Management**

Saudi Arabia is a participant in the Red Sea and Gulf of Aden Environment Program (PERSGA) and has ratified the Kuwait Regional Convention for Co-operation on the Protection of the Marine Environment from Pollution, and the Regional Convention for the Conservation of the Red Sea and Gulf of Aden Environment which require controls on pollution and the implementation of coastal zone management policies (IMO/ROPME/UNEP, 1984). The Environmental Protection Coordination Committee (EPCCOM) co-ordinates environmental activities between different agencies in the Kingdom (Dakkak *et al.*, 1984a). Responsibility for fisheries is vested in the Ministry of Agriculture and Water. There are minimum size limits for some fish species but little other regulation of the fishery (Morgan, 1985).

Throughout most of Saudi Arabia, marine conservation and environmental protection are the responsibility of the Metereology and Environment Protection Administration (MEPA). MEPA is in charge of the development of a coastal zone management policy, the identification of protected areas and the preparation of oil spill dispersant regulations, and has promulgated a comprehensive set of air and water quality standards (IUCN/UNEP, 1985a and b). The Marine Projects Group of the MEPA Natural Resources Directorate is responsible for co-ordinating long-term monitoring programmes to assess the state of the marine and coastal environments and for the development of management strategies. Efforts to develop a Coastal Zone Management Plan for both the Gulf and Red Sea coast are summarised in IUCN (1987a), resulting from a series of studies carried out by IUCN (Crossland *et al.*, 1987; IUCNb and c). A national public awareness programme has been established involving the preparation of educational and publicity materials (Dakkak *et al.*, 1984a).

In the two Royal Commission cities of Al Jubayl on the Gulf and Yanbu al Sinaiyah on the Red Sea, environmental responsibility lies with the Royal Commissions. Marine monitoring is continually carried out in these two areas and a coastal zone management plan is now effectively underway. As yet Saudi Arabia has no permanent marine protected areas except for areas established within the jurisdiction of the Royal Commission at Yanbu in the early 1980s (*see separate account*). However a large number of sites have nominally been given interim protection pending more detailed management studies and legislation (*see below*).

**Recommendations**

Dakkak *et al.* (1984a and b) provide details of future activities to be carried out by MEPA in relation to the marine environment. New legislation is being prepared to ensure that environmental protection of natural resources is concomitant with further socio-economic development. The proposed legislation will take account of the concepts contained in the "Basic Paper on the Islamic Principles for the Conservation of the Natural Environment" (Ba Kader *et al.*, 1984).

Proposals for a Coastal Zone Management Plan are outlined in IUCN (1987a) and are based on the survey work carried out with the assistance of IUCN, as described earlier. In 1984, a list of resolutions was presented by EPCCOM to the Council of Ministers which provided a framework for conserving the coastal and offshore marine environment of the Saudi Arabian Red Sea and Gulf of Aden. The Council of Ministers Decision No. 271 ratified most of these and included approval for the designation of 26 marine protectorates along the Red Sea coast, in which there would be a general moratorium on development, pending the preparation of detailed conservation plans for each area. In addition a number of other areas have been proposed for marine protectorate status, as listed in IUCN (1987a), making a total of 46 areas for the Red Sea and 11 for the Gulf, although several can be combined into larger areas to facilitate future management.

Management objectives for marine protectorates include the provision of natural reference areas for monitoring, recreation, aesthetic appeal, and the protection of critical habitats. A national plan for combatting oil pollution and a requirement that industries should reduce pollutant emission and remove any waste generated, were also approved. A ban on new coastal infilling, dredging and solid waste disposal in a zone including all territorial waters and 100 m inland of the high water mark, or the furthest annual extent of tidal inundation was recommended but not ratified. The Coast Guard was recommended as the enforcement agency (IUCN, 1987d).

Three of the marine protectorates approved by EPCCOM are situated on the southern coast of the Red Sea. However, because of the different physical conditions found on this coast compared with the north, such as characteristic reefs and mangroves, an additional eight coastal areas were recommended by IUCN, seven on account of their mangrove stands and one for its recreational value. It has also been recommended that the coastal fringe of the Asir National Park should be regarded as a marine protectorate for management purposes (IUCN, 1985a). These additional areas would take into consideration the presence of the Red Sea endemics *Chaetodon larvatus* and *Tibia insulaechorab* which are found there (IUCN, 1985b).

The 46 sites recommended as coastal and marine protectorates for the Red Sea in IUCN (1987a and b) is as follows:

* = listed in Dakkak *et al.* (1984b) as "proposed protected marine conservation sites"; many of these sites are also listed in other reports such as IUCN (1985a).
° = core area designated by EPCCOM in 1984

1. Humaydah Beach, Bay and Island, and inlet to south of Humaydah Bay (Al Humaydah*)° (*see account for* Al Humaydah)
2. Ras Suwahil, Bir Marshah, Wadi al Hiqaf including Ras Suwahil as Kabir.
3. Maqna North Beach
4. Tiran Islands*° (*see separate account*)
5. Al Muwailih
6. Sharm Yahar to Sharm Jubba
7. Sharm Zubeir
8. coastline south of Sharm Zubbeir

9. Ghubbet Bal'aksh*°
10. Sharms Dumagha and Antar*°
11. Sharms Habban and Munaibira* (Munaybirah)° (*see account for* Al Wajh to Qalib)
12. Wajh Bank and islands* (*see account for* Al Wajh to Qalib)
13. Qalib Islands*° (*see account for* Al Wajh to Qalib)
14. Umm Lajj*°
15. Al Hasani, Libana, Maliha and Umm Sihr Islands*°
16. Ras Abu Madd to Sharm Hasi (Sharms Haban, Hasi and Mahar*)°
17. Sharm al Khaur*° (*see account for* Yanbu al Sinaiyah)
18. Sharm Yanbu*° (*see account for* Yanbu al Sinaiyah)
19. Yanbu City Conservation Area (Royal Commission Area*)° (*see account for* Yanbu al Sinaiyah)
20. Shi'b Green Reef Complex
21. Marsa al Usalla (Mersa al Usaila*)°
22. Mersa Tawil
23. Mastura Beach*°
24. Mersa as Sarraj*°
25. Marsa umm Misk
26. Haramil Island
27. Ra's Hatibah*° (Ra's Hatiba)(*see account for* Jiddah region)
28. Jiddah Salt Marsh* (*see account for* Jiddah region)
29. Shu'aiba*° (and reefs at Qadd Humais) (*see separate account*)
30. Abu Duda lagoon; an extension of the boundary of the Asir National Park to include the coastal fringe has also been recommended (IUCN, 1985a) (*see account for* Ra's Abu Kalb to Ash Shuqayq)
31. Qishran Island*° (*see account for* Qishran - Ra's Mahasin).
32. North Inner Farasan Bank reefs and islands (near Ra's al Askar*)° (*see account for* Qishran - Ra's Mahasin).
33. South Al Qunfudhah (Qunfidah); beach heavily used for recreation.
34. Khor Amiq and Raka (*see account for Ras Abu Kalb to Ash Shuqayq*)
35. Khor Nahud (*see account for Ras Abu Kalb to Ash Shuqayq*).
36. Marqa Island
37. North and South Sharm Wasm (Jabal Wasm*), Al Quhma (Qahmah) Village and Qadimbal Island° (*see account for Ras Abu Kalb to Ash Shuqayq*).
38. Khor Itwad; mangrove, some moderate quality coral reef, fishing.
39. Khawr al Ja'afirah area, including Ra's at Tarfa* and Firan, Shaira and Farafir Islands (*see account for* Farasan Archipelago)
40. North Outer Farasan Bank reefs and islands*° (*see account for* Farasan Archipelago)
41. Farasan Archipelago*°(*see account for* Farasan Archipelago)
42. Shi'Abu Al Liqa (*see account for* Farasan).
43. Shi'b Al Kabir (*see account for* Farasan).
44. South Jizan Beach (*see account for* Farasan).
45. Khor al Wahla (*see account for* Farasan).
46. Oreste Point (*see account for* Farasan).

General recommendations for environmental impact survey work, research needs, monitoring and the construction of an underwater coral reef observatory near Jiddah are given in Crossland *et al.* (1987) and IUCN (1985a). Recommendations for improved management of the Red Sea coast fisheries are given in Crossland *et al.* (1987). The collection of shells and corals for the souvenir trade should be controlled as it develops. There is an urgent need for an environmental education programme with specific reference to coastal and marine natural resources. Within the marine protectorates, information on fishery activities, such as catch rates, should be collected. It might be necessary to have certain areas designated no-fishing zones but in general restrictions on artisanal fishermen in marine protectorates should be minimal. Coastal chalets should not be permitted as they prevent other people using the coast. Further field survey work should be carried out to assess the relative value of proposed sites. Five sites have been selected which typify the different ecosystems identified along the Red Sea coast and have been recommended for more detailed study (Crossland *et al.*, 1987): 1) near Bir Marshah, in the Gulf of Aqaba, 2) the Wajh Bank, 3) Ra's Hatibah north of Jiddah, 4) Khor Nahud (18°17'N) and 5) south of Jizan.

The following areas have been recommended for inclusion in the coastal and marine protectorate system for the Gulf coast (IUCN, 1987a and d) (earlier recommendations were given for some of these areas in IUCN (1983) and are briefly mentioned):

1. The islands of Karan, Kurayn, Jana, Al Jurayd, Harqus and Al Arabiyah and their associated reefs as six separate marine protectorates; this area has also been recommended as a national park or biosphere reserve (*see separate account*).
2. Tarut Bay Complex: North Tarut Bay and south-west coast of Tarut Island (no reefs but other important marine resources).
3. Abu Ali/Dawhat and Dafi/Musallamiyah Complex; Dawhat Al Musallamiyah (between Manifa and Al Jubayl) was recommended previously as a national coastal park; this area is currently undeveloped but ARAMCO is planning a facility at Ra's Tanajib (IUCN, 1982c); 5. Dawhat ad Dafi, west of Al Batinah Island and Abu Ali has no reefs but is an important wetland.
4. Al'Uqayr Bay; the Al'Uqayr-Az Zakhnuniyah-Ra's Abu Maharah area hs also been recommended as a coastal park or biosphere reserve (no reefs).
5. Southern Gulf of Salwah (no reefs).
6. Safaniya/Manifa Bay Complex.

An additional seven areas have been created or recommended for recreational development:

7. Dawhat Zalum (Zaham) Half Moon Bay) (offshore reefs important for recreational use)
8. Ras Tanajib
9. Abu Ali
10. Jubail
11. Ras Tanura
12. Al Uqayr
13. Dawhat as Sayh (Sunset Beach) and much of the shore north to Al Khobar

Areas (1,2,7) were considered high priority, (3) medium priority and the rest low priority. Dawhat Al Khurays (no reefs, but important for birds) and Khawr Mushurrabah (no reefs) were suggested for protection in earlier recommendations. The establishment of a Coastal Management Commission for Tarut Bay which could function in a similar fashion to the Royal Commission for Al Jubayl and Yanbu is recommended (IUCN, 1987d). Recommendations for further research on the Gulf coast in relation to management are given in IUCN (1987d) and IUCN/UNEP (1985b).

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## AL HUMAYDAH AND ADJACENT REEFS

**Geographical Location** Al Humaydah (Al Humaida) lies south of Haql in the north of the Gulf of Aqaba; 29°12'N, 34°55'E.

**Physical Features** Jezirat Ruweijil (Humaydah Island) lies in a large bay opposite the fishing village of Al Humaydah. It has a rocky peak. There is a well developed fringing reef on the outer side where the reef drops into deep water, and shallower reefs and a lagoon with sandy bottom on the landward side. Between the headland south of Haql and the headland north of Sharm ad Dama'ir (adh Dhamayir), there is 10 km of what appears to be the best section of fringing reef on the Saudi Arabian Aqaba coast (IUCN, 1982b).

**Reef Structure and Corals** Five distinct coral communities have been recognized (Crossland *et al.*, 1987).

**Noteworthy Fauna and Flora** No information.

**Scientific Importance and Research** This is the only area of the Saudi coast in the Aqaba Gulf with good reefs. It was surveyed by the Tropical Marine Research Unit in 1982 (IUCN, 1982b).

**Economic Value and Social Benefits** No information.

**Disturbance or Deficiencies** No information.

**Legal Protection** None.

**Management** None.

**Recommendations** The area comprising Humaydah Beach, Bay and Island, and the inlet to the south of Humaydah Bay has been recommended as a coastal and marine protectorate, the core area having been designated by EPCCOM in 1984 (IUCN, 1987b; Dakkak *et al.*, 1984b). Detailed proposals are currently in preparation (IUCN, 1987b). The area was originally recommended for Reserve status by Ormond (1980).

## AL WAJH TO QALIB, INCLUDING WAJH BANK

**Geographical Location** Northern Red Sea; coastline running from Al Wajh (Wejh) (26°16'N, 36°28'E) to Qalib including Raiyikha Island, Marduna Island, Sharm Habban, Sharm Munaibira, Marsa Martaban (26°00'N, 36°38'E) and Wajh Bank. The latter includes: Ra's Karkuma (Ra's Karkame) (25°50'N, 36°36'E), Wadi Hamdh (25°55'N, 36°40'E), Hawar Island, Umm Uruma Island, Mashabih Island (25°37'N, 36°33'E), Shaybara Island (25°30'N, 36°50'E) and Waqada Island.

**Physical Features** From Al Wajh to Ra's Karkuma there are rocky islands up to 60 m high in deep water, with sandy islets and mangroves. The Wajh Bank is a very large complex of reefs surrounding a central lagoon (20 x 10 km) containing many small patch reefs and mangroves. A complex shallow water area (10 x 10 km) with a sandy bottom and shoals is found inshore of Shaybara Island. At Wadi Hamdh there are extensive mudflats and mangroves and no fringing reef. Mashabih is a large island with a 50 km long barrier reef complex on its seaward side extending north and south. There are numerous current channels through the barrier and a lagoon area behind the south-east branch of the barrier (IUCN, 1982b).

**Reef Structure and Corals** The coral fauna is poor north of Ra's Karkuma, but there is high coral cover on the Wajh Bank patch reefs (IUCN, 1982b).

**Noteworthy Fauna and Flora** Ra's Karkuma is notable for seagrass beds and mangroves. North of the Wajh Bank the coast is noted for its fish and shells, with chitons and limpets in the tidal pools. Shells are also good at Wadi Hamdh, particularly olive and tibia shells. The south-west corner of Mashabih Island is an important turtle nesting area (IUCN, 1982b). Gallagher *et al.* (1984) describe the status of seabirds nesting in the area; the islands of the Mashabih complex are believed to be particularly important. Major stands of mangrove are found at the Wajh Bank particularly on Waqada Island (Birema Island) (IUCN/UNEP, 1985a). Dugong *Dugong dugon* may frequent the large shallow seagrass beds of the Wajh Bank (Crossland *et al.*, 1987).

**Scientific Importance and Research** A survey was carried out by IUCN (1982b). The Wajh Bank area contains a collection of extensive and varied habitats of biological interest, including mangroves, seagrass beds, islands and interesting coastal flats at Wadi Hamdh.

**Economic Value and Social Benefits** There is reported to be spectacular diving at Mashabih. Fishing is an important activity for the villagers on the shore opposite the Wajh Bank (IUCN, 1982b), and spiny lobsters are of major importance (Ross Group, 1966).

**Disturbance or Deficiencies** The Wajh Bank is an isolated region with little or no effects from development.

**Legal Protection** None.

**Management** None.

**Recommendations** Three sites within the area have been proposed for marine and coastal protectorate status: Sharms Habban and Munaibira (Munaybirah), the Wajh Bank and islands and the Qalib Islands, core areas at Sharms Habban and Munaibira and the Qalib Islands having been designated by EPCCOM in 1984 (Dakkak *et al.*, 1984b; IUCN, 1987b). The Wajh Bank area was originally recommended as a National Park (IUCN, 1982b; Ormond, 1980).

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## FARASAN ARCHIPELAGO AND ADJACENT COAST

**Geographical Location** Red Sea; southernmost stretch of Saudi Arabia's coastline, from Shib Abu al Liqa (17°40'N, 42°10'E), south of Ash Shuqayq (Al Shuqaiq), to Oreste Point on the border with North Yemen. Includes the following islands and sites: Ra's at Tarfa (17°10'N, 42°20'E); Farafir Island (17°00'N, 42°25'E); Dhi Dhahaya Island (16°52'N, 41°35'E); Sarso Islands (16°53'N, 41°32'E); Jizan (16°56'N, 42°33'E); Farasan Kebir Island (16°40'N, 42°00'E) and the Barri/Rumayn group of islands to the south.

**Area, Depth, Altitude** the archipelago covers about 600 sq. km (Buttiker and Grainger, in press); max. alt of islands 30 m.

**Physical Features** The Farasan Archipelago with over 80 islands, together with the Farasan Bank to the north, consists of open water and widely scattered reefs and shoals. The area has fairly shallow water and sedimentary conditions, and less well developed reefs than Saudi's north coast, although Dhi Dhahaya Island and the Sarso Islands have extensive well-formed reefs. Farasan Kebir has murky waters on the landward side of the island, and depths of 30-50 m over a large area. There is a town near the central part of the island (IUCN, 1982b). The coastal area is dominated by extensive sand dunes which reach the sea, and by mangroves with relatively few areas of old reef flat or other outcropping rock. Three different areas have been distinguished in the Farasans: 1) an inshore flat-bottomed channel (15-50 m deep) with scattered reefs and islands, 10-20 km wide in the north and up to 35 km wide in the south; 2) the Farasan Bank, lying off shore in waters of about 100 m depth, has numerous shallows, reefs and islands; in the north it is less than 20 km wide but off Ash Shuqayq and Jizan in the south it is 110 km wide; it is bordered to the west by an abrupt drop-off to more than 250 km; 3) beyond the drop-off, in the north, numerous shallow reefs and islands. In the centre and to the south there is a flat terrace, which drops further west into water over 2000 m deep (Crossland *et al.*, 1987). A general description of the Archipelago is given in Bahafzallah (1984) and the geology is described by Macfadyen (1930a and b).

**Reef Structure and Corals** Along the mainland coast there are no fringing coral reefs, but there are patches of algal reef which are composed of fringes or offshore patches of calcareous red algae, reaching low water level and covered by *Sargassum* (Sheppard, 1984). They are similar to the shallowest parts of the more developed reefs north of this area, but the algal construction may be 1-4 m deep. Corals provide less than 1% cover, although *Siderastrea* and several faviids are fairly common. Despite the lack of recent coral reef, there are areas where fossil reef occurs at high water level and slightly above, indicating that much higher coral diversities existed in the past.

Sarso Island and the smaller Sindi Sarso are elevated reefs whose origin probably dates back to the early Pleistocene. Eroded corals are visible on the surface and their steep slopes show sub-fossil corals still in their growing positions (Schäfer, 1967). Abrasion terraces lie to the east of Sarso (100-150 m wide) and to the west of Sindi Sarso (about 20 m wide) and are separated by a channel about 1.4 km wide and 100 m deep. Recent reefs have developed on the terraces and their zonation has been described by Klausewitz (1967). Forty-four hermatypic coral species in 20 genera have been collected (Scheer, 1967; Scheer and Pillai, 1983).

**Noteworthy Fauna and Flora** Terrestrial fauna of the Farasan Islands is described in Buttiker and Grainger (in press). At Jizan there are mangroves and many birds use the reservoir area. Ra's at Tarfa, an area isolated from the main road by salt flats, has one of the largest concentrations of mangroves along the Red Sea coast (Crossland *et al.*, 1987). The *Sargassum* beds to the south of the headland and the waters around Farafir Island may be an important nursery ground for Spanish Mackerel *Scomberomorus commersoni*. In the Barri/Rumayn group, Spanish Mackerel are abundant, and are important for the fishing fleet in Jizan (IUCN, 1982b). Gallagher *et al.* (1984) list the seabird colonies in the area (Crossland *et al.*, 1987).

**Scientific Importance and Research** The Archipelago was visited by the Xarifa Expedition in 1957 and the Meteor Expedition in 1964, when the Sarso Islands were studied (Schäfer, 1967).

**Economic Value and Social Benefits** The Farasan area is a major fishing area and has been studied by staff of the marine laboratory at Jiddah (Nawwab, 1976). The Saudi Fisheries Company is accumulating catch statistics for finfish and shrimp (Dakkak *et al.*, 1984b). A summary of the work carried out in the area is given in Crossland *et al.* (1987).

**Disturbance or Deficiencies** Cousteau and Diolé (1971) reported large areas of dead coral and considered that the reefs had been damaged by waste from shipping. The islands are largely undisturbed although some minor threats are described in Buttiker and Grainger (in press).

**Legal Protection** None.

**Management** None.

**Recommendations** Within the area, a number of coastal and marine protectorates have been recommended (IUCN, 1987b). Additional recommendations for this area are given in Dakkak *et al.* (1984b), IUCN, 1982b, 1984b and 1985a):

- Farasan Archipelago, including Disan Island, Khor Seqid on Farasan Seqid, Khor Maadi, Farasan Kebir, Zifaf Island and Gomari Island; core area designated by EPCCOM in 1984.
- North Outer Farasan Bank reefs and islands, including representative ring reefs/atolls, Sharbain, Dorish Island, Al Umm Island complex, Dhahrat Miraya (east and west), Wasaliyat (north and south) Islands, Sumair Island; core area designated by EPCCOM in 1984.
- Shi' Abu Al Liqa, a mangrove-lined creek with a moderate to poor fringing reef on the west side.
- Shi'b al Kabir, a mangrove stand and a moderate to poor but quite extensive fringing reef; it is important for fishing.
- Khawr al Ja'afirah area and islands, including Firan, Shaira and Farafir; Ra's at Tarfa has mangroves, is important for fishing and has recreational potential; the shoreline east of Ra's at Tarfa is an important mangrove area.
- South Jizan Beach, a 2 km stretch of beach of major recreational value.
- Khor al Wahla, an important mangrove area.
- Oreste Point, on the North Yemen border, also an important mangrove area.

Part of the Farasan Bank and Archipelago was recommended earlier as a National Marine Park, to consist of a series of small Reserves, scattered over a large buffer zone allowing many activities such as commercial fishing and housing (IUCN, 1982b). Ormond (1980) proposed a Biosphere Reserve for the area and stressed the need for careful zoning and management because of the large area involved and the importance of the fisheries. Recommendations for the islands are given in Buttiker and Grainger (in press) and include the establishment of a protected area.

## JIDDAH (JEDDAH) REEFS

**Geographical Location** Red Sea coast from north of Ra's Hatibah (21°55'N, 38°57'E) to south of Ra's Al Aswad (21°23'N, 39°04'E), including outer reefs of Shib al Kebir, 14 km off Sharm Obhur and Abu Faramish, Mismari Reef and Abu Madafi'.

**Physical Features** There is a broad fringing reef, sometimes up to 1 km wide, along the Jiddah coastline, separated from the shore by a lagoon a few metres deep. The slope descends to at least 30 m depth in most parts. Further off shore there is a complex series of patch reefs, at least some of which lie on a platform (Bouchon and Antonius, 1983) reminiscent of the one found at Yanbu (*see separate account*). At Ra's Hatiba there are extensive salty lagoons, with low flat, fossil coral islands, sandy islets and some mangroves. Sharm Obhur is a large deep creek with coral reef on either side and seagrass beds. The strongest winds come from the north-west and create moderate wave action at both the fringing reefs and the offshore patch reefs. Chemico-physical characteristics are described by Saad and Fahmy (1984).

**Reef Structure and Corals** A few of the offshore patch reefs have been briefly examined by IUCN (1982a). Abu Faramish, about 24 km off Sharm Obhur, has two outer patch reefs with reef slopes which drop steeply to 15 m depth and then more gradually to 20-50 m depth with a maximum coral cover of 50%. South-east of these is Shib al Kebir, which is shaped like an atoll and whose steep reef slope also supports about 50% live corals. This reef has caused many shipwrecks. Near the lighthouse, the slope and coral cover are similar except where dynamiting has taken place and cover drops to 10%. Other offshore reefs such as Mismari and Abu Madafi are reported to be well developed with good coral cover, but there are no details.

More research has been carried out on the fringing reef near Jiddah, particularly near the North Corniche where the central region has been studied in some detail by Sheppard (1984 and 1985b) and IUCN (1982a and 1984a). The Corniche road and developments have been built largely on the reef flat and lagoonal areas. The broad reef flat, where it is unaffected by development, is about 1 m deep and covered for the most part with coarse sediments and scattered seagrasses. From the reef crest, the reef slope descends gradually to about 3 m depth with 30% hard coral cover, the most conspicuous species being *Acropora hyacinthus* and *Porites*. The slope then steepens to nearly 90° to 10 m depth, supporting the same cover of hard corals of a higher diversity, and with 50% soft coral cover. From 10 to 25 m depth, the slope is less steep, but has the same fauna. Between 28 and 35 m, hard and soft coral cover and coral diversity gradually decline until soft substrate is encountered at 35-40 m depth.

Bouchon and Antonius (1983) found four different coral communities on the fringing reefs and offshore reef system. A poor community was found in the lagoon where a high sedimentation rate prevailed; an assemblage largely dominated by *Stylophora pistillata* was found on the reef flats subjected to strong wave action and periodical emersion; a homogenous and rich coral community occurred down to 40 m depth on the outer reef slopes where ecological conditions were favourable, and a deep community adapted to low light levels was found from 50 to 60 m depth. A check list of coral species has been compiled. The biota of the reef flats around Jiddah is described by Hughes (1977). The reef at Sharm Obhur has been described by Behairy and Jaubert (1985) and Montaggioni *et al.* (1986).

**Noteworthy Fauna and Flora** Dolphins (Delphinidae) have been seen. Turtles (Chelonidae) nest on sandy islands, and ospreys *Pandion haliaetus* on the sandy islets and mangroves. There is a report of tern (Sterninae) nesting on Aiqa Island. The salt marshes are important for wading birds (IUCN, 1982a). At Abu Faramish the commercial fish *Naso* spp. and *Lutjanus gibbus* are abundant. Garden eels (Heterocongrinae) have been reported at 12 m depth at Abu Faramish and at 40 m depth off Sharm Obhur. The seabirds of the area are described in Gallagher *et al.* (1984). Khafaji and Meinez (1984) describe marine algae.

**Scientific Importance and Research** The physical conditions in the deep creek of Sharm Obhur give rise to interesting coral reef communities (Hiscock, 1972). Nawwab (1976) describes the marine laboratory 10 km north of Jiddah. Numerous studies have been carried out in this area by members of the Faculty of Marine Science, King Abdulaziz University, several of which are published in Saad (1984), including work on foraminifera, molluscs, pollution, sediments, algae and seagrasses. A study assessing the impact of the developing city on the marine environment has been carried out by IUCN (1982a).

**Economic Value and Social Benefits** The diverse and productive communities of coral reefs, mangroves and seagrass beds provide an important biological base for local artisanal fisheries in the Jiddah region (IUCN, 1982a; Oakley, 1984). At Ra's Hatibah there are mounds of opened *Trochus, Strombus, Murex* and *Tridacna*, a result of heavy collecting for food. There is excellent diving at Mismari Reef and Abu Madafi' (IUCN, 1982a).

**Disturbance or Deficiencies** Antonius (1985) recorded coral mortality due to White- and Black-band disease. Much of the reef is relatively untouched by development but certain areas have been badly affected. The major problems are infilling and construction causing heavy sedimentation and turbidity. Extensive reef damage is seen near the northern corniche road which extends 12 km north of Jiddah, and was built partly on the reef flat itself and partly in the lagoon and shallow water areas, in some places only 20 m from the fringing reef. It caused heavy loss of coral and there is perhaps only 10-20% coral cover left. Shallow water habitats such as seagrass beds have also been destroyed. There are plans to extend the road up the north side of Sharm Obhur, past the Palace and perhaps beyond Ra's Hatibah. The southern corniche, south of Jiddah, is further from the reef and no signs of impact are noticeable, but there are plans for its extension.

The city has expanded rapidly along the coast in the last 10-15 years. In the Old King's Palace area there is much beach housing, although north of this area to Ra's Hatibah there is no coastal development. There is little disturbance at Ra's Hatibahal though some construction for a desalination plant is evident and there are plans for the development of recreational facilities. In the 1970s *Chaetodon semilarvatus* juveniles were collected here for export for the aquaria trade. The Jiddah fringing reef has suffered damage from construction work, especially of desalination plants near the edge of the reef flat which has caused extensive although localized mortality. Large amounts of rubbish, builders' rubble and steel rods have scoured the living coral. There is some evidence of recolonization by *Pocillopora* but it will take years to recover. The creek at Sharm Obhur is being degraded through infilling at the back end and oil tipping and the seagrass beds are disappearing. Shells, populations of predatory fish and branching corals are reported to have become scarcer and siltation from outboards is affecting corals (Ormond, 1980). Dredging to construct channels through the reef is occurring north of Jiddah and a channel has been dredged between Sharm Obhur and the Old King's Palace. Eutrophication and algal growth have turned parts of Sharm Obhur green. Behairy and El-Sayed (1984) report on dissolved organic matter in the water in this area and Abbas and Haddad (1984) briefly describe the impact of sewage pollution. Building plots now extend 40 km north of Jiddah and waste and sewage are discharged into the sea and are not flushed out of the lagoon. The salt marshes are heavily littered with rubbish as is the recreational beach along the northern corniche. Oil is dumped on the salt marshes south of Jiddah and small oil spills from ships have contaminated the beaches, but not severely. El-Rayis *et al.* (1982) provide further information on pollution in this area.

The expatriate community has had a considerable impact on the reef through recreational activities (Ormond, 1980). Coral, shell and fish collecting for the souvenir and aquarium trade has been going on for about 10 years, having been introduced by the expatriate community but there is no known export except of mother-of-pearl (Hiscock, 1972). The collection of reef flat fauna by foreign workers has a great impact and the recreational activities of the local population have had some impact. The lagoon at Jiddah Corniche Beach and Sharm Obhur is now largely devoid of corals, apart from small, broken colonies, as a result of trampling (Antonius, 1984) and Giant Clams *Tridacna maxima* have been virtually eliminated (Bodoy, 1984). Fauna in the coastal lagoon is much reduced and the absence of invertebrate grazers is likely to be the cause of the increased amount of algae. Nawwab (1976) reported that the combination of a large market demand in the 1970s and accessibility of the reefs had caused a noticeable decline in fish populations as a result of handlining. The impact of spearfishing by local fishermen is described by Oakley (1984); large fish are uncommon in areas where spearfishing is intensive. Dynamiting occurred in 1980 at the lighthouse on Shib al Kebir.

**Legal Protection** None.

**Management** None known.

**Recommendations** Ra's Hatiba and the Saltmarsh area have been recommended as marine and coastal protectorates, a core area at Ra's Hatiba having been designated by EPCCOM in 1984 (Dakkak *et al.*, 1984b; IUCN, 1987b). Earlier recommendations included Ormond (1980) who proposed a Reserve to the south side of the entrance of Sharm Obhur Creek, close to the marine station which could have tourist and educational value and would be available to scientists from the laboratory. A Marine Park was proposed for Ra's Hatiba for recreational, educational and scientific purposes, to include some of the offshore reefs, and with careful development of recreational facilities to avoid damage to the area. It was suggested that the fringing reef to the south of the point plus the large shallow area to the north should be investigated for its biological and fisheries significance.

IUCN (1982a) recommended a coastal environment management plan to minimize the side effects of development in the Jiddah area. It was suggested that the following actions should be considered:-

- The creation and implementation of solid and liquid waste discharge standards.
- Identification of areas for, and methods of, toxic and non-toxic waste disposal.
- The control and regulation of coastal development and construction.
- The control of fishing and animal collecting from reefs, including recreational fishing and collecting.
- Establishment of special management zones (*see below*).
- Initiation of a long term biological monitoring programme.

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## KARAN, KURAYN, JANA, AL JURAYD, HARQUS, AL ARABIYAH AND ASSOCIATED REEFS

**Geographical Location** Eastern coast of Saudi Arabia; the islands lie off shore between the towns of Safaniya and Al Jubayl on the Gulf coast. Al Jurayd (27°11'N, 49°59'E) lies about 35 km north-east of Al Jubayl; Jana (27°21'N, 49°54'E) lies 20 km further north; Kurayn (27°38'N, 49°49'E) and Karan (27°42'N, 49°49'E) lie 60 km off shore and a further 30 km north, and Harqus (27°56'N, 49°41'E) lies 90 km off shore and is the furthest north. Al Arabiyah (27°46'N, 50°10'E) lies about 40 km east and slightly north of Karan, and is the furthest off shore.

**Area, Depth, Altitude** An area of several thousand square kilometres; the islands are mostly found on the edge of the 20 fathom (36.6 m) contour (Basson *et al.*, 1977) and have a maximum altitude of 4 m. The maximum depth of coral reef formation in all cases is about 15 m, and the tops of most patch reefs are at low water level. Patch reefs vary from a few to a few hundred metres in diameter, with occasional reefs several kilometres long. Around the islands the reefs may extend seaward for a few kilometres from the shore (Basson *et al.*, 1977). The sizes of the coral islands are: Al Jurayd 732 x 282 m; Jana 1105 x 300 m; Kurayn 312 x 251 m; Karan 2024 x 632 m; Harqus 259 x 76 m, and Al Arabiyah 488 x 267 m.

**Physical Features** The major physical factor affecting the reefs is the shallow and enclosed nature of the Gulf which results in high salinities of 38-41 ppt in the open coastal areas, and up to 70 ppt in more enclosed bays. It also causes temperatures to range seasonally from 10° to 35°C near the coast; even well off shore the range is 15° to 33°C. Sedimentation is fairly high due to the extensive areas of soft substrate (Basson *et al.*, 1977). These environmental controls are more extreme and fluctuate to a greater extent nearer shore, and reefs therefore tend to be located off shore.

The tops of many patch reefs accumulate sand which may emerge at low tide. In the islands this process has extended to become a permanent condition. Most of the islands are covered with scrub or bushes. Harqus has no vegetation and high seas sometimes wash over it. Al Arabiyah has low bushes only. Karan, the largest and most remote island, has a dense cover of bushes up to 1 m high. Kurayn has scattered bushes only. Jana has a dense cover of bushes up to 1 m high. Al Jurayd has dense cover on about two thirds of the island.

**Reef Structure and Corals** Hundreds of patch reefs are found scattered in this area, particularly in the northern section. Karan, Jana and Al Jurayd are the main fully developed coral reef and island ecosystems. Harqus and Kurayn are very small, and Kurayn is really part of the Karan reef system (Burchard, 1982). Fringing reefs off Karan and Jana are described by Basson *et al.* (1977) and Burchard (1979). A reef platform or reef flat extends seaward 2-3 km on the windward side and half that width on the leeward side. Depth at low tide is a metre or less which results in very high water temperatures and salinity. The reef flat is covered with loose sand, dead cemented coral, beach rock and a few corals, such as *Stylophora* and *Cyphastrea*, with small *Porites* colonies occurring towards the edge, as well as *Goniastrea, Platygyra* and *Acropora*. On windward sides there are low banks of coral rubble behind the reef crests. Grooves and spurs may be found on the seaward edge with increasing live coral which forms a slightly raised crest.

The reef slopes to a terrace at 10 m depth and then drops to the sea bed at 18 m (Basson *et al.*, 1977). At 2.5 m depth the dominant biota is the coralline alga *Lithothamnion*. Corals which do occur are small, massive forms which can withstand moderate to severe wave energy, such as *Porites, Platygyra* and other faviids. Maximum coral development is found from 2.5 m to 15 m, where coral cover and diversity are greatest. This part has a steady incline, interrupted in places by extensive flat terraces, especially one at 9 m depth which occurs in many places, representing the position of sea-level in the Pleistocene. The terraces accumulate sand, and hence are colonized by fewer corals, although large *Porites* and *Acropora* may be common.

On the reef slopes, several zones are recognized (Basson *et al.*, 1977). Above the terraces, prominent buttresses of massive coral species such as *Porites* define a "buttress zone" which extends to 4 m depth. From 4 to 6 m depth, smaller colonies are abundant, and the dominant genus is often *Goniopora*. From 6 to 10 m depth, tabular *Acropora* corals are the most conspicuous component although there is a high diversity of other corals, particularly encrusting forms; this is the most diverse zone. Between 10 and 12 m depth, *Montipora* is dominant. At 12 m depth, many reefs terminate, but where a hard substrate continues, delicate bushy *Acropora* and *Pocillopora* provide very high cover and extensive areas may be entirely covered by a single species. Below this level and extending to the foot of the reefs, foliaceous forms become abundant, including *Echinophyllia* and *Turbinaria*, together with small faviids and mussids. Beyond a depth of 15 m, the substrate flattens and becomes more unconsolidated but hermatypic corals still occur, particularly *Turbinaria*. The amount of talus increases below this and the habitat grades into coarse sands. About 55 species of coral have been recorded from the reefs (Burchard pers. comm.), a low number for the Indian Ocean region, which reflects the stressful environmental conditions.

**Noteworthy Fauna and Flora** The islands contain the richest reefs of the Gulf and serve as important nesting sites for birds and turtles (Basson *et al.*, 1977; Burchard, 1982). At Jana and Karan large numbers of conch *Strombus decorus persicus* spawn in summer. Cone shells are common, notably the venomous *Conus textile* and *C. sumatrensis*. Reef fish are abundant and are described in Basson *et al.* (1977). The reefs are local centres of extremely high productivity and are consequently frequented by important commercial and game fish species including, at Jana Island Reef, Pompano *Trachinotus blochi*, Kanaad or King Mackerel *Scomberomorus commersoni*, several species of large jacks and tuna, Sailfish *Istiophorus gladius*, Black Marlin *Makaira indica* and a variety of large sharks (Selachimorpha). The reef also plays an important or crucial role as a nursery for the young of many fish species, both reef residents and those which as adults occupy other habitats.

The islands are particularly important breeding sites for turtles. The total population of Green Turtles *Chelonia mydas* using these islands can be estimated at about 1200-1500 adults, of which only about one third visit the islands to breed in any given year, plus an unknown but certainly large number of juvenile and immature animals. The population of Hawksbill Turtles *Eretmochelys imbricata* is less well known, but is certainly smaller. For both species, Karan Island is the most important breeding site, followed by Jana Island. Together these two islands probably account for about 80% of the turtle breeding in the Gulf (Basson *et al.*, 1977; Ross and Barwani, 1981).

The islands are vitally important for the Gulf seabird populations, mainly terns (Swift Tern *Sterna bergii*, Lesser Crested Tern *S. bengalensis*, Bridled Tern *S. anaethetus* and White-cheeked Tern *S. repressa*), since they are the only areas free from mammalian predators. All the islands are used as breeding sites; Karan is the most important with some 20 000 pairs of Lesser Crested Terns and smaller numbers of at least three other species, including the Swift Tern (1000+ pairs). Jana, Al Jurayd and Kurayn, probably in that order, are also important. Breeding attempts on Harqus frequently fail when storm seas wash over the island, destroying the eggs or young birds. Bird breeding on Al Arabiyah is affected by the military and other technical installations and by the continuous presence of people on the island. The Socotra Cormorant *Phalacrocorax nigrogularis* has 100 pairs on Kurayn and large colonies on other islands (Basson *et al.*, 1977). Gallagher *et al.* (1984) give a full account of the breeding seabirds of the islands.

**Scientific Importance and Research** Preliminary surveys have been carried out by Basson *et al.* (1977) and IUCN (1982c and 1983) and more recently the islands have been surveyed by IUCN (1987d). Some studies on the effect of oil on coral at Al Jurayd Island have been carried out by ARAMCO (IUCN, 1982c).

**Economic Value and Social Benefits** The islands are important for fisheries, recreation (particularly Al Jurayd and Jana) and education (Burchard, 1982; Price, 1982a). Group dive tours to Al Jurayd are organized from Al Jubayl. The reefs around the islands support an important artisanal fishery (IUCN, 1987d).

**Disturbance or Deficiencies** Currently there is little disturbance (IUCN, 1982c and 1983; Price, 1982a) but the area is potentially threatened by construction of installations or facilities on the islands, industrial fishing operations and collecting by souvenir hunters, spearfishermen and oriental contract labourers in search of sea food and marketable souvenirs (Burchard, 1982). An oil processing and storage facility has been proposed for Jana Island and there are rumours of a Coast Guard base planned for Al Jurayd. Oil spilled in the Gulf as a result of hostilities has affected the beaches and coincided with major coral mortality on the reefs (Burchard pers. comm. to Sheppard, 1985). The impact of oil on the reef at Al Jurayd was investigated by Legore *et al.* (1983).

Al Arabiyah is occupied by a Saudi Arabian Frontier Forces post and a variety of radio installations serving navigational and telecommunications purposes (Burchard, 1982) and this has affected the nesting of turtles and birds. Turtle nesting on Al Jurayd may have declined recently as a result of visits from local fishermen who sometimes slaughter the nesting females or dig up their eggs (Basson *et al.*, 1977; Ross and Barwani, 1981). Sheets of weathered oil and large amounts of driftwood occur on Jana's windward beach severely hampering the breeding turtle population (IUCN, 1982c).

An increasing number of residents are visiting the islands particularly Jana and Al Jurayd, for SCUBA diving. As a result some anchor damage and shell collecting occurs, with potential disruption to the nesting turtles (IUCN, 1982c).

**Legal Protection** None.

**Management** None.

**Recommendations** The islands have been recommended as six separate coastal and marine protectorates, the boundaries extending to 20 m depth, and were designated as such by EPCCOM in 1984 (IUCN, 1987d). It is suggested that this area would be suitable for biosphere reserve status. Earlier recommendations included National Park status for the area (Burchard, 1982; IUCN, 1982c and 1983; Price, 1982a) and nature reserve status for the three main islands (Burchard, 1982). It was suggested that Karan, with Kurayn, could form a "wilderness area" off-limits for other than bona fide scientific parties and professionally guided nature-study groups. Jana, which is much more accessible from the mainland town of Al Jubayl, could become a primary site for non-destructive field research and education, hopefully based on the Marine Research Centre planned for Al Jubayl. It could also be used for recreational uses such as SCUBA diving. Recreational use of Al Jurayd could be allowed to continue, subject to certain restrictions and to guidance from the Marine Science Centre and/or Park Wardens to avoid damage to the reef ecosystem (Burchard, 1982; IUCN, 1982c and 1983).

Guided trips to Al Jurayd could become part of the programme of the planned Al Jubayl public aquarium. Restrictions applicable to visitors to Al Jurayd might include prohibition on rubbish dumping, collection of marine life (coral, shells, fish, turtles, turtle eggs, birds, birds eggs), fishing and spearfishing, camping during the bird and turtle breeding season, and visitors would be required to obtain a permit. Similar but more stringent rules should apply to Jana Island and visits to Karan Island would normally be limited to authorized scientific research parties (Burchard, 1982).

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## QISHRAN - RA'S MAHASIN

**Geographical Location** The Red Sea; south of Jeddah including Al Lith, Abu Latt Island, Dohra Island, Marmar Island, Al Jadir Island, Malathu Island, Shiba' Ammar, Shib Murabba, Ra's al Askar and Ra's Mahasin on the coast and further south the islands Sirrain, Safiq, Long, Fara and Pelican; from 20°15'N, 39°50'E (Qishran) to 19°10'N, 41°5'E (Al Qunfudhah).

**Area, Depth, Altitude** The coastline is about 30 km long from Qishran to Ra's Mahasin and a further 70 km long from Ra's Mahasin to Al Qunfudhah; water is less than 20 m deep for at least 1 km off shore; offshore islands arise from deeper water.

**Physical Features** The coastal area is a low lying plain (sabkah). The coastal waters are relatively turbid and shallow, especially in bays and wadis where mud flats and mangroves are the dominant habitat. This applies especially to the Ra's Mahasin area where there is a large shallow bay dominated by *Avicennia marina*. Much of the shoreline south of this is sheltered by a line of islands and reefs lying 10 km off shore, which greatly reduce the effect of the waves, and is dominated by mangrove, with no reefs. Near the southern end at Al Qunfudhah a substantial fringing reef is present for at least 10 km. Abu Latt is a rocky island with a fringing reef to the south of Qishran; Dohra, Marmar, Al Jadir and Malathu are similar sandy islands. At Shiba' Ammar the reef has formed a partially enclosed atoll containing a silty lagoon. There is a complex of reefs at Shib Murabba, and extensive coral reefs from Ra's al Askar to Pelican Island (IUCN, 1982b). Further details are given in IUCN (1984b).

**Reef Structure and Corals** The offshore islands have coral reefs among the mangroves but no details are available on their morphology or coral fauna. The outer walls of the atoll-like reef at Shiba 'Ammar are covered with gorgonians and black corals (IUCN, 1982b).

The seaward fringing reef, a patch reef 1 km off shore, and two turbid water patch reefs in the bay at Ra's Mahasin have been studied in more detail (Sheppard, 1984 and 1985b). Only the reef flat of the offshore patch reef supported live corals. It had a live cover of 20% coral and the seaward edge had 90% cover of the green alga *Caulerpa*. The reef edge in the other areas was dominated by the brown alga *Sargassum*. The sublittoral of the offshore patch reef and fringing reef had a relatively high coral diversity (over 80 species) and included a shallow water zone dominated by *Porites* and tabular *Acropora*. The reef slopes extended to about 20 m depth before grading into soft substrate. The patch reefs in the bay had reduced coral cover and high sedimentation, and their coral faunas were a depauperate subset of those found on the more exposed reefs. At Al Lith there is a very turbid fringing reef whose narrow reef flat extends to a reef slope which descends to about 3 m depth. *Galaxea* is the dominant genus on the reef slope and *Porites* is abundant on the reef crest. Sedimentation is very severe.

The broad (200 m) fringing reef flat at Al Qunfudhah is covered with a layer of mud, and terminates to seaward in a zone of *Sargassum*. The reef slope descends to 7 m depth before abruptly terminating on horizontal soft substrate. Coral cover on the slope is 65-75% at all depths. *Porites* is dominant in shallower water and large colonies of leafy corals such as *Turbinaria* and *Echinopora* in deeper water.

**Noteworthy Fauna and Flora** The northern Qishran area is notable for its extensive mangroves. These also occur at Al Lith and are fairly abundant on Long Island and Pelican Island and in places link one island to the next. Sharks (Selachimorpha) occur in the canyon at Shiba' Ammar and several whale sharks *Rhincodon* have been sighted north-west of Shib Murabba. Dugongs *Dugong dugon* have been sighted and turtles and manta rays (Mobulidae) occur frequently in the Qishran area. The four sandy islands are visited by turtles and large numbers of terns (Laridae) and boobies *Sula* spp. (IUCN, 1982b; Crossland *et al.*, 1987).

**Scientific Importance and Research** The area was surveyed by IUCN (1982b) and Sheppard (1984 and 1985b).

**Economic Value and Social Benefits** The offshore islands are important for birds (IUCN, 1982b). Ra's al Askar, Ra's Mahasin and the offshore islands are important commercial fish spawning areas. There is some recreational use and people have been observed camping on Ra's Mahasin (IUCN, 1985a).

**Disturbance or Deficiencies** There is a area of dead mangrove near Ra's Mahasin which may be due to camel grazing (IUCN, 1985a). The reef flat at Al Lith is dominated by green algae for over 1 km, probably a result of organic enrichment from the town.

**Legal Protection** None.

**Management** None.

**Recommendations** Qishran Island and the North Inner Farasan Bank reefs and islands, to include Janabiyat and Melma Island, Ras Kinnateis, Ras Al Humara, Umm al Qandil, and the north arm of Ghubbet al Mahasin; Umm al Gharaniq Island; Ghubbet al Mahasin south, including the coastline from Ras Ahmar to Ras Mahasin; Sirrain Island; Safiq and Umm Ali Islands; and Pelican Island complex have been recommended as coastal and marine protectorates. Qishran was designated as such by EPCCOM in 1984 (IUCN, 1987c). Early recommendations (IUCN, 1982b) were for two protected areas: a) the group of offshore islands between Ra's al Askar (19°50'N, 40°40'E) and Ra's Morwiya (19°20'N, 41°E), including Safiq, Long, Fara and Pelican Islands and b) Qishran Island (20°15'N, 39°50'E) and the surrounding area. The area from Ra's al Askar to Ra's Mahasin could be managed as a Multiple Use Management Area or Marine Park (Dakkak *et al.*, 1984b; IUCN, 1985a).

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## RA'S ABU KALB TO ASH SHUQAYQ (AL SHUQAIQ) INCLUDING ASIR NATIONAL PARK

**Geographical Location** Southern Red Sea coast from 18°40'N to Ash Shuqayq at 17°43'N, including the following islands and shore sites: Dorish Island opposite Ra's Abu Kalb, Zuqaq Island, Wasaliyat Island, Simayr Islands group (including Dhahrat Simayr Islands) and the coastal area of Asir National Park from north of Ad Darb to south of Ash Shuqayq (17°43'N).

**Area, Depth, Altitude** Coastal area of Asir National Park extends for some 100 km; depth in the coastal region is less than 10 m; max. depth around the islands is about 40 m.

**Physical Features** The coast is a low-lying plain (sabka) alternating with dunes and very occasionally volcanic outcrops. Fringing reefs extend to about 5 m depth where soft substrate is encountered, sand and mud continuing seawards for at least 1 km at less than 10 m depth. The sea is fairly turbid in the vicinity of embayments and mangroves but clearer elsewhere. A climatological survey of the Asir National Park was carried out by Zapletal (1984).

**Reef Structure and Corals** The fringing reef is the southernmost in the Saudi Red Sea before the coast becomes covered with supralittoral and sublittoral dunes. It is separated from reefs to the north by many kilometres of mangroves (Sheppard, 1984 and 1985b) and is divided into sections of irregular length by muddy embayments and expanses of mangroves. Most of the reef flat is over 100 m wide and is covered with sand and various sparse seagrasses. The reef crest is of calcareous red algae to which dense stands of *Sargassum* are attached. The reef slope is very gentle, descending to about 5 m depth over a distance of about 100 m. The shallower parts are dominated by *Acropora*, including *A. formosa*, *A. grandis* and *A. nobilis* which do not extend further north in the Red Sea. The deeper part has a higher diversity and is dominated by massive *Porites* and tabular *Acropora*. Zuqaq Island, Dorish Island and Wasaliyat Island have well developed reefs (IUCN, 1982b) but no details of the corals and structure are available. There are no noteworthy fringing coral reefs off the Asir National Park.

**Noteworthy Fauna and Flora** Turtles have been reported from the east end of Dorish Island. Boobies *Sula* spp. are present on Simayr Island in the north and there are reports of boobies nesting on Dorish Island in the 1970s (IUCN, 1982b). There are a number of important mangrove stands (IUCN, 1985a).

**Scientific Importance and Research** A survey of the islands was carried out by IUCN (1982b) and of the fringing reefs and mangroves by Sheppard (1984) and IUCN (1985b).

**Economic Value and Social Benefits** The Asir National Park is popular with visitors. It is intended to provide facilities at Ash Shuqayq for swimming, boating etc. (Anon., n.d.; Clark and Vanderbilt, 1982). The very attractive reef at Zuqaq Island would provide an excellent diving site.

**Disturbance or Deficiencies** There is very little use of the reef. However, there are about 40 beach chalets on the Asir National Park coast between Widan and Khor Al Makra, the fences of which prevent access to the beach (IUCN, 1985a).

**Legal Protection** The Asir National Park, designated in 1976, is subject to directives issued by Prince Khaled Al-Faisal, Governor of Asir Province; the Park includes the shore but does not extend into the sea (Anon., n.d.).

**Management** No information.

**Recommendations** Within this area, a number of coastal and marine protectorates have been recommended (IUCN, 1985a and 1987c):

- Khor Amiq and Raka (18°30-18°35'); two sharms with good quality mangroves and a fringing reef of moderate quality; the site is important for artisanal fishing.
- Khor Nahud (18°20'-18°15'N); a fringing coral reef and mangrove area, important for artisanal fishing and with good potential for tourism.
- North and South Sharm Wasm, Al Quhma (Qahmah) Village and Qadimbal Island; Al Quhma (18°10-17°50'N) was designated a marine protectorate by EPCCOM in 1984, and a minor extension of the boundary is recommended to include high quality mangrove stands; the area

receives heavy recreational use, is important for artisanal fishing and the mangroves are suffering some overgrazing by camels; description in IUCN (1984b).

- Abu Duda lagoon; an extension of the boundary of Asir National Park has been recommended to encompass marine habitats; the Park has been considered for World Heritage Site listing (IUCN/UNEP, 1985).

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## SHU'AIBA

**Geographical Location** Red Sea, south of Jiddah; Shu'aiba is at 20°40'N, 39°30'E; Qadd Humais lies to the south, 20°15'N, 39°25'E.

**Area, Depth, Altitude** Fringing reef descends to about 10 m.

**Physical Features** Shu'aiba is a large area bordering a low-lying coastal plain with a system of complex lagoons and channels. Mangroves extend over 1 km inland in depressions which are connected to the open sea by channels. There is a broad fringing reef in some areas, while in others the reef is separated from the shore by a lagoon, 500 m wide and at least 10 m deep. In such cases there is a narrow coral fringe along the shore. Turbidity is high on both the coral fringe and the fringing reef (IUCN, 1982b).

**Reef Structure and Corals** The fringing reef flat is 100-1000 m wide and supports a limited coral fauna. On the reef slope in shallow water, branching corals, particularly *Acropora*, dominate and cover 60% of the substrate to 3 m depth. From 3 to 10 m depth there is a higher diversity of corals, but coral cover is only 23%, with soft corals such as *Xenia* providing 65% cover (Sheppard, 1985b). The hydrozoan *Millepora* is abundant at all depths. Off shore, Qadd Humais is a system of low sandy islets and coral reefs in deep water (IUCN, 1982b) but no details of the reefs have been recorded. Antonius (1984) gives additional information on this area.

**Noteworthy Fauna and Flora** The very large tidal depression over 1 km landward of the reefs is surrounded by mangroves. The area has abundant fish, sharks (Selachimorpha) were recorded at Qadd Humais, and a Dugong *Dugong dugon* has been reported in the Shu'aiba area (IUCN, 1982b).

**Scientific Importance and Research** The area has been well mapped by IUCN (1984a), although research is very limited.

**Economic Value and Social Benefits** The Shu'aiba area is close enough to Jiddah to provide considerable amenity value and offers a diverse range of different habitats of great local interest.

**Disturbance or Deficiencies** A road crosses the mouth of the lagoon and may have an impact on the water circulation. A desalination plant is planned for the area (IUCN, 1982b). The reefs were considered by Antonius (1984) to be in relatively good condition compared with those near Jiddah.

**Legal Protection** None.

**Management** None.

**Recommendations** Shu'aiba and the reefs Qadd Humais are recommended as a marine protectorate, a core area at Shu'aiba having been designated by EPCCOM in 1984 (Dakkak *et al.* 1984b; IUCN, 1987). The Shu'aiba area was earlier recommended as a Nature Reserve and the reefs and deep waters at Qadd Humais were recommended for protection (IUCN, 1982b and 1984a).

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## STRAITS OF TIRAN INCLUDING TIRAN AND SINAFIR NATURAL RESERVES

**Geographical Location** Northern Red Sea, at the mouth of the Gulf of Aqaba, including Tiran Island (27°58'N, 34°35'E) and Sinafir Island (27°55'N, 34°40'E). Burqan (Barqan) Island lies to the east.

**Area, Depth, Altitude** Tiran covers an area of 19 sq. mi. (49 sq. km).

**Physical Features** The islands are scenic with well developed reefs in very clear water. Tiran is arid with a small area of salt marsh but has extensive reef adjacent to very deep water. Sinafir has extensive reef to the south-west with very clear water and depths of over 500 m. Burqan Island has fairly well developed reef in clear water with an extensive sandy area between island and reef (IUCN, 1982b). Jackson, Gordon, Woodhouse and Thomas reefs are situated in the centre of the Straits and are in exceptionally clear water; vertical walls drop to a ledge at 70 m and then the drop-off continues to 1000 m. Tides create strong channels between these reefs, and only two channels are considered navigable: between Gordon Reef and the Sinai shore, and between Jackson Reef and Tiran. The area is sheltered from the prevailing north winds and is influenced primarily by southerlies and local wind conditions.

**Reef Structure and Corals** No published information.

**Noteworthy Fauna and Flora** The density and diversity of reef life is very high at Jackson, Gordon, Woodhouse and Thomas reefs (Clark and Vanderbilt, 1982). Fish are abundant including sharks (Selachimorpha) and manta rays (Mobulidae) at Sinafir Island. On adjacent Saudi Arabia coast, Aynunah Bay (28°02'N, 35°12'E) is the only recorded northern locality for the Red Sea endemic damselfish *Pristotis cyanostigma* (Crossland *et al.*, 1987). Green Turtles *Chelonia mydas* nest on Tiran and Sinafir Islands (Groombridge, 1982; Sella, 1981). Dugong *Dugong dugon* have been recorded at Tiran. Tiran is a haven for a variety of birds due to the lack of mammalian predators. Breeding birds include 20-40 pairs of Osprey *Pandion haliaetus*, 2-4 pairs Sooty Falcon *Falco concolor*, White-eyed Gull *Larus leucophthalmus*, Caspian Tern *Sterna caspia*, Lesser-crested Tern *S. bengalensis*, White-cheeked tern *S. repressa*, Spoonbill *Platalea leucorodia*, Reef

Heron *Egretta gularis*, Little Green Heron *Butorides striatus*, Kentish Plover *Charadrius alexandrinus* and Brown-necked Raven *Corvus ruficollis* (Bruun, 1983).

**Scientific Importance and Research** A survey was carried out by IUCN (1982b). Considerable ornithological work was carried out by Israeli scientists when Tiran was under Israeli control.

**Economic Value and Social Benefits** The area around Tiran Island is good for fishing. The Sinafir reefs are of outstanding natural beauty and the Jackson and Gordon reefs are very popular dive sites and used by visitors at Sharm el Sheikh.

**Disturbance or Deficiencies** The Straits are an extremely important shipping channel and their narrowness and the presence of reefs means that there are regular shipwrecks with inevitable damage to the reefs.

**Legal Protection** Under the Prime Minister of Egypt's Decree 1068 of 1983 and Law 102, Tiran and Sinafir were declared Natural Reserves within the same boundary as Ras Muhammad, and are therefore subject to the same regulations.

**Management** Tiran first came under military control in 1967 when it was taken by the Israeli forces and was managed as a strict nature reserve during turtle and seabird breeding seasons. Since then, the continual military presence has ensured that the island has remained relatively undisturbed (Zimmerman, 1984). With its return to Egypt in 1982, the Multinational Force and Observers patrol the area and are reported to avoid the breeding areas of birds and to cause no disturbance (Bruun, 1983). The regulations of the reserve area are not, however, enforced.

**Recommendations** The Tiran Islands have been recommended as a marine protectorate, to include Sharm Mujawwan and the coastal fringing reef (a core area having been designated by EPCCOM in 1984), Tiran Island, Gordon's Reef, Sha'b abu Tinun, Sinafir Island, Shusha Island and associated reefs, Al Fungur, Bir Beach, Al Khuraybah Beach, Aynunah Bay, Barqan Islands, Yuba, Walih and the Julaijila group, and the Sila Islands chain (Dakkak *et al.*, 1984b; IUCN, 1987b). There were a number of earlier recommendations. Part of the islands, including Sinafir and Ras Abu Fasma and the mainland sites of Sharm Mujawa (just inside the Gulf of Aqaba), Ras Fartak and Al Khurma were recommended as a reserve by IUCN (1982b). It was thought that Tiran, in a politically sensitive location, might not be suitable for incorporation in the reserve. However the International Council for Bird Preservation is anxious that Tiran should be protected (Bruun, 1983) and there seem to be good reasons for encouraging the implementation of the recently declared Egyptian reserve area. Jackson and Gordon reefs were considered a high priority for protection by Clark and Vanderbilt (1982).

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## YANBU AL SINAIYAH AND SURROUNDING REGION

**Geographical Location** Central Red Sea, from Ra's Baridi south to Yanbu al Sinaiyah; 24°N, 38°E. Yanbu al Sinaiyah is a new industrial city and oil terminal located about 20 km south of the old port of Yanbu' al Bahr.

**Area, Depth, Altitude** 100 km of coast; patch reefs off shore to 20 km; maximum depths on reef slopes 40 m, but less on fringing reefs and inner patch reefs.

**Land Tenure** The city of Yanbu al Sinaiyah is a Royal Commission City and the administration of the city controls the use of the land.

**Physical Features** Fringing reefs are mostly continuous along the coast, interrupted by various sharms which contain muddy areas with mangroves and seagrasses. Several areas, such as between Yanbu al Sinaiyah and the old port of Yanbu' al Bahr, consist of a series of complex, muddy lagoons, connected by channels with the open sea and fringing reef, which lies several hundred metres from the shore. There is a shallow offshore platform, about 10 x 40 km in area, which appears to be part of a much larger structure which extends along much of the central Saudi Arabian coast up to 10 km off shore, at least as far as Jeddah (Antonius pers. comm. to Sheppard, 1985). The surface of the platform is 20-50 m deep, has very high relief, and supports some of the most extensive reefs in the region (EESAL, 1983). Further north where the offshore platform is absent, the fringing reef is less than 50 m wide and descends steeply to over 50 m deep. The coastline at Sharm Yanbu consists of low-lying hills and lagoonal shallows. Sharm al Khaur has lagoonal shallows, seagrass beds and beaches.

Winds blow strongly from the north-west during the day such that the outer reefs receive the greatest wave energy, but cyclones do not occur. There is a marked attenuation of median wave heights, from of 0.57 m on the seaward side of the outer reefs to less than 0.1 m at the fringing reef (Georeda Ltd, 1982; Saudi Arabian Tetra Tech, 1980). Sedimentation is low and water clarity is high on the outer reefs, but both parameters deteriorate at the inner and fringing reefs. Back-reef slopes in every case have higher turbidity than their corresponding seaward slopes due to material pumped over the reef flats, but no quantitative data are available. Temperature varies seasonally from 20 to 30°C at the surface with thermoclines of about 2°C between 10 and 20 m depth. Salinity is about 40 ppt and is slightly higher in winter and lower in summer (EESAL, 1983). Oversaline intrusions have not been detected and fresh water input is very rare. As is typical for reef waters, nutrient levels are mostly very low with no gradients across the area.

**Reef Structure and Corals** Within the area of Yanbu al Sinaiyah there are four basic types of reefs (EESAL, 1983; Sheppard, 1985a; Sheppard and Sheppard, 1985):

1. Fringing reefs are generally broad, extending up to 1 km from the shore. The shoreward parts are covered in a layer of mud up to 1 m thick and the mangrove *Avicennia marina* forms thick stands in sheltered areas on the reef flats.
2. The inner reefs include groups of simple, nearly circular patch reefs such as those in the south-east of the area, elongated ribbons running parallel with the shore and a complex of reefs which are separated from the fringing reef by a series of channels and holes. Patch reefs are often only 400-500 m from the shore but are separated from

the fringing reef by soft substrate at a depth of over 10 m. The fore-reef slopes of the inner reefs descend steeply to about 20 m from which point a more gentle gradient supports a mixture of sand and extensive coral growth which may rise in broad knolls above the substrate.

3. From the inner reefs (or from the fringing reef when the former are absent) the substrate shelves downwards to about 50 m over a horizontal distance of approximately 1-3 km. Immediately before a steepening of the slope to 100 m depth there are several patch reefs, termed mid-reefs. All are small, having diameters of 200 m or less, but they support coral communities of very high species diversity.
4. The outer reefs are located on the offshore platform which is separated from the shore by water at least 50 m deep and for the most part over 100 m deep, for a distance of about 5 km. Reefs reach the surface in groups on both the seaward and shoreward sides of the platform (but rarely between), forming a barrier reef. They vary in shape from small and circular to elongated ribbons and include crescents and atoll-like rings. In between the substrate is largely sandy. The outermost reef series is located at the extreme edge of the platform, which plunges to over 500 m depth. The shoreward reefs have slopes which descend to a nearly horizontal substrate at 20-30 m depth where sand is predominant. The back-reef slopes of all the outer reefs are slightly more turbid than the fore-reef slopes, as a result of sediment being washed off the reef flat.

A total of 96 hermatypic coral species in 45 genera have been recorded (Sheppard, 1985b; Sheppard and Sheppard, 1985). Cluster analysis of the species recorded from over 100 sites revealed 13 coral assemblages. One is found on reef flats and depauperate areas adjacent to mangroves, four were dominated by combinations of three *Acropora* species and occurred in areas with varying degrees of high wave exposure, while the remainder were of higher diversity and found on reef slopes of intermediate to low exposure. The diversity is exceptionally rich compared with other areas of the Red Sea investigated to date. Fringing reefs to the north of Yanbu have high coral diversity, similar to that of the outer reefs described above. In general, *Pocillopora verrucosa* is the dominant species on shallow reef fronts and slopes (Fadlallah, 1985).

**Noteworthy Fauna and Flora** Turtles nest on the mainland north and south of Sharm Al Khaur and on the beaches of the offshore islands. Dugong *Dugong dugon* are reported from the area. At Sharm Yanbu there are flamingos, oysters and a few small mangrove stands on the south shore. The mangrove stands of *Avicennia marina* in Yanbu al Sinaiyah are an important feeding area for ducks, flamingos and other birds (IUCN, 1982b; Sheppard, 1982). Gallagher *et al.* (1984) describe the status of seabirds in this area.

**Scientific Importance and Research** Reef studies have been carried out to fulfil the requirement that the marine environment should be monitored during the construction of coastal facilities in the development of the Royal Commission City. Considerable information on physical parameters has been collected, but this is mainly in the form of reports, deposited in the city library. The extensive facilities available in Yanbu, and a substantial database, provide a very favourable base from which to carry out marine research in the Red Sea (EESAL, 1983). Pichon (pers. comm. to Sheppard, 1985) and IUCN (1982b) briefly surveyed the area. The structure of the reefs in this area is considered to be one of the most complex known from the Red Sea and coral diversity is high (Sheppard and Sheppard, 1985).

**Economic Value and Social Benefits** These reefs are adjacent to a large population whose use of the coastal region is largely recreational, with few artisanal fisheries. Sharm al Khaur, Sharm Yanbu and much of the coast is becoming of increasing recreational value to the expatriates working in Yanbu (IUCN, 1982b).

**Disturbance or Deficiencies** Yanbu al Sinaiyah is a new industrial and oil city. Construction started in the late 1970s, during which about 2-3 km of fringing reef and inshore patch reefs were affected to various degrees, ranging from complete removal by dredging or covering with landfill, to minor impacts from sedimentation (EESAL, 1983). Less than 2 km from the site of construction, however, the reef is undamaged, as are the offshore patch reefs, apart from the reef near the cement factory, 50 km north of Yanbu' al Bahr. This discharges large quantities (some 80 tons a day) of untreated dust which settles along the coast and reef flats; there are plans to double the capacity of the factory. The oil pipeline serving Yanbu al Sinaiyah has a capacity of 100 Mmt/year. The Royal Commission operates a "zero-discharge" policy (IUCN/UNEP, 1985a), but presumably there is potential for oil spills and pollution. The mangrove stands have suffered a reduction in size from their original area (Sheppard, 1982). Far Eastern workers from the cement factory and from Yanbu al Sinaiyah may collect turtles and their eggs.

**Legal Protection** Various procedures exist for the control of marine discharges and other potentially disruptive marine activities. These are monitored by the Royal Commission and authorized on a permitting system. Three areas of a few hectares each have been designated as conservation areas by the Royal Commission, including the principal mangrove stands in the region and, in one case, some of the fringing reef to seaward. They are situated on the coast within the new city limits. The rich offshore reefs were not covered by these conservation areas in 1984.

**Management** The Royal Commission for Jubail and Yanbu delegate the research and monitoring of the reefs and other coastal ecosystems to various companies located in the city. The Yanbu Development Plan contains clauses designed to ensure the protection of neighbouring marine and littoral habitats (EESAL, 1983; Gallagher *et al.*, 1984; Sheppard, 1982).

**Recommendations** Three sites in this area are recommended as marine and coastal protectorates: Sharm al Khaur, Sharm Yanbu and the Royal Commission (Yanbu City Conservation) Area and were designated as such by EPCCOM in 1984 (Dakkak *et al.*, 1984b; IUCN, 1987b). IUCN (1982a) recommended the creation of Ra's Jarbu Nature Reserve to cover a large area, primarily for dugongs, turtles and seabirds.

# SEYCHELLES

## INTRODUCTION

### General Description

The Seychelles Islands are spread over the Indian Ocean between 5° and 10°S and 45° and 56°E. They can be divided into two groups: the inner granitic islands to the north-east and the outer coralline islands to the south and west. The inner granitic islands, with a total land area of 277 sq. km, are spread over the 43 000 sq. km of the Seychelles Bank and are considered to be fragments of the ancient Gondwanaland. With St Helena in the Atlantic, they are the only granitic oceanic islands in the world. The highest peak on the largest island, Mahé (152 sq. km), is nearly 1000 m above sea-level. Only two islands on the Bank, Bird and Dennis, are sand cays. The second group of islands spreads westwards and southwards from the granitic group towards the coasts of Africa and Madagascar. They are composed of numerous low islands or atolls in several clusters, each located on the top of volcanic structures of various sizes. Piggott (1961) classifies these according to different coral island types. Salm (1978) provides a list of the main Seychelles Islands and Stoddart (1984a) gives a general description.

There are pronounced bathymetric differences between the waters of the Seychelles Bank, which have an average depth of less than 20 m and a maximum depth of no more than 100 m, and those surrounding most of the coral islands and atolls which have the characteristic steep outer slopes of true, oceanic atolls. The southern islands lie in the west-flowing South Equatorial Current, while the northern islands are in the path of the east-flowing Equatorial Counter Current. The latter, lying nearer the Equator, are generally less exposed than those nearer the coast of Africa which are affected more by the south-east trades. All the islands are largely unaffected by cyclones (Couper, 1983; Stoddart, 1971). Annual rainfall shows a strong gradient from 1500 to 2500 mm on the granitic islands, to less than 1000 mm in the western coral islands such as Aldabra. Tides range from only about 1 m in the eastern granitic islands to over 2.5 m in the atolls nearer the African mainland.

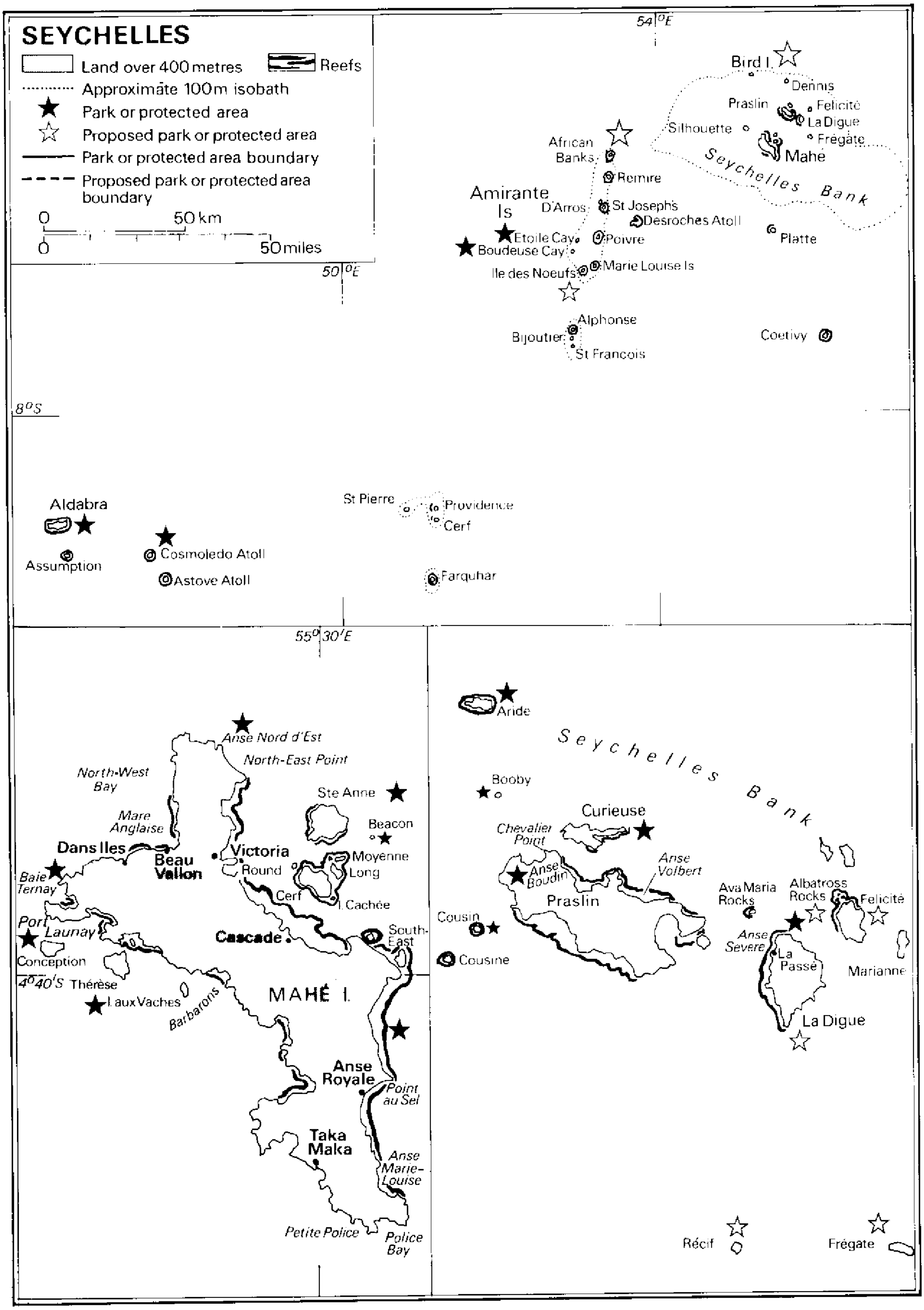
Although the coral reefs of the Seychelles are scattered over a vast area of the Western Indian Ocean and are among the most extensive in the world, they are among the least studied (Stoddart, 1984a). Detailed studies are largely limited to studies carried out on the fringing reefs of Mahé, at the time of the International Indian Ocean Expedition in 1964, and a few publications on the reefs of Aldabra (*see separate account*). Nevertheless, there is a considerable amount of information, often geomorphological, floristic and faunistic, on the reefs, some of which was collected in the course of the Percy Sladen Trust Expeditions of 1905 and 1908 (Gardiner, 1907).

In the granitic islands, only scattered parts of the coastline support fringing reefs (Stoddart, 1984a). However, patch reefs arise from the shallow Seychelles Bank in many areas. Surface temperatures around Mahé vary from about 27° to 32°C, although close inshore the water is warmer and may approach the lethal limits for fauna (Taylor, 1968). Tides are mixed, mainly semi-diurnal, with strong inequality between successive lows. Tidal amplitude is 1.8 m at greatest springs and lowest tides occur around noon when solar effects are strongest and also correspond with the period of highest rainfall. Annual rainfall is about 2000 mm. Wave action is strongest on sides facing the south-east trades although local sheltering effects within the granitic groups of islands complicates the pattern.

The Mahé reefs have a fairly narrow reef flat formed by the gradual constructive advancement of corals and calcareous algae (Taylor, 1968). Reefs are found on those stretches of the coast where exposure is greatest, although exposure is not severe in terms of the Indian Ocean generally. The east coast has a virtually continuous fringing reef extending about 27 km from north of North-east Bay to Anse Marie Louise in the south, interrupted only by a few granite headlands. It averages 500-1300 m in width and the reef slope descends to 5-30 m. Where the reef is exposed to the south-east trades, it has a reef edge with spurs and grooves, a strong algal ridge, a cobble ridge and a veneer of rippled sand with no seagrasses. In more sheltered areas seagrass is more extensive and the zonation is more conspicuous. From South-east Island to North East Point, the reef is unbroken for 12 km and reaches a width of over 2 km. The reefs around the north-east offshore islands are described in the account for St Anne Marine National Park. North of Victoria, the reef edge becomes irregular and dissected and the reef is reduced to a series of coral knolls.

Braithwaite (1971) and Rosen (1971) describe three distinctive features of the east coast Mahé reefs. An *Acropora* assemblage, more typical of open waters, is found on gentle slopes to about 20 m depth. A *Porites* assemblage, dominated by *P. lutea*, flourishes best in calm waters which are sometimes turbid and have low light levels and are subject to fluctuations in salinity and water temperature. Colonies are found as free-standing growth pinnacles up to 10 m in diameter, or as a growth frame superimposed on a bank of some other origin. A third assemblage is basically a calcrudite accumulation of coarse fragments of coral. Some areas seem to be reefs but have little coral growth, and other distinctly non-reefal areas have prolific coral growth (Braithwaite, 1971). Rosen (1971) found a finer zonation within the above scheme, *Pocillopora, Acropora* and *Porites* characterizing assemblages in order of decreasing water movement.

On the west coast, reefs are poorly developed although there are narrow reef platforms 30 m wide off promontories exposed to the south-east trades. These occur mainly in bays, such as Anse à la Mouche and Baie Lazare, where they may be interrupted by river mouths. Several of these have seagrass beds and few have strongly defined reef edges. Reefs at Port Launay and Baie Ternay are described in a separate account. North West Bay, to the north of Baie Ternay is a major tourist area, centered on Beau Vallon, and is popular for diving and snorkelling. There is a continuous fringing reef from Beau Vallon north to Sunset Hotel, described in Salm (1977). Snorkelling is good at the end of the beach and along Glacis, where Taylor (1968) describes a small algal


SEYCHELLES
Land over 400 metres
Reefs
Approximate 100m isobath
Park or protected area
Proposed park or protected area
Park or protected area boundary
Proposed park or protected area boundary
0 50 km
0 50 miles
54°E
50°E
8°S
55°30'E
4°40'S
Bird I.
Dennis
Praslin
Felicité
La Digue
Silhouette
Frégate
Mahé
Seychelles Bank
African Banks
Remire
Amirante Is
D'Arros
St Josephs
Desroches Atoll
Platte
Etoile Cay
Poivre
Boudeuse Cay
Ile des Noeufs
Marie Louise Is
Alphonse
Bijoutier
St Francois
Coetivy
Aldabra
Assumption
Cosmoledo Atoll
Astove Atoll
St Pierre
Providence
Cerf
Farquhar
Aride
Seychelles Bank
Booby
Curieuse
Chevalier Point
Anse Boudin
Anse Volbert
Praslin
Cousin
Cousine
Ava Maria Rocks
Albatross Rocks
Felicité
Anse Severe
La Passe
Marianne
La Digue
Récif
Frégate
Anse Nord d'Est
North-East Point
North-West Bay
Ste Anne
Mare Anglaise
Beacon
Dans Iles
Beau Vallon
Victoria
Moyenne
Round
Long
Baie Ternay
Cerf
I. Cachée
Port Launay
Cascade
South-East
Conception
Thérèse
I. aux Vaches
Barbarons
MAHÉ I.
Anse Royale
Point au Sel
Taka Maka
Anse Marie-Louise
Petite Police
Police Bay

ridge off the reef. The best diving is around Ilot, off the north point of the Bay. South-west of Beau Vallon there is a continuous fringing reef to Dans Iles, which is particularly good off Petit Port. In the south-west, Police Bay has a good coral reef, and reefs are found at Petit Police, Police Point and Barbarons. Thèrese Island, just south of Port Launay has a fringing reef along the north-west shore with few corals but abundant fish (Salm, 1977). Further information on the reefs of Mahé is given in Lewis (1968 and 1969) and Lewis and Taylor (1966).

Silhouette Island, to the north-west of Mahé has little coral but there is a rich fish fauna around the granite boulders (Salm, 1977). Praslin has 26.8 sq. km of fringing reefs, which are up to 2850 m wide on the west coast but only about 380 m wide on the east (Stoddart, 1984a). The reefs of Curieuse National Park, off the north coast of Praslin are described in a separate account. Cousin Island reefs are also described in a separate account. La Digue has 4.5 sq. km of fringing reefs which extend up to 610 m from shore and are widest on the west and south-east (Stoddart, 1984a). With the exception of the La Passe area, the entire western shore is bordered by a shallow lagoon and well-developed fringing reef. In the south, the fore-reef plunges steeply to the sandy channel floor at 12 m. Much of the *Acropora* is dead. Salm (1977) describes some of the reefs at Anse Severe and at the Ava Maria Rock, 2 km north-west of La Digue. Sites on Praslin, La Digue, Cousin, Cousine and Frégate are described very briefly by Parkinson (1984). Albatross Rocks, to the north of Felicité Island, are described by Salm (1977). The two coral islands, Bird and Dennis, on the north of the bank are described in a separate account. Fifty-one scleractinian coral genera (45 hermatypes) have been described from the granitic islands (Stoddart, 1984a).

Little is known about the reefs of the coral islands and atolls to the south of the Seychelles Bank and most studies have been confined to the reef flat. Even for Aldabra, there is only one study of the reef biota deeper than about 1 m (Barnes *et al.*, 1970 and 1971). However, many of the islands have been visited and are described in Stoddart (1970). Plate Island (Platte) and La Perle Reef (5°50'S, 55°E) are mentioned in Gardiner (1907). Plate is a tiny guano island (0.53 sq. km) with extensive reefs (26.6 sq. km) to the north-west extending 3 mi. (4.8 km) off shore. Coetivy (7°5'S, 56°E) is a cay formed entirely of sand, with dunes 75 ft (23 m) high, situated on a reef platform of 14.2 sq. km, described by Gardiner (1907) as a fringing reef. This is narrow in the north but up to 2 mi. (3.2 km) wide in the south. There is a very gradual slope to the east with no clear reef edge. The bottom at 20 m has a good cover of the seagrass *Cymodocea*. There is abundant *Lithophyllum*, but no algal ridge or grooves and spurs. In the west there are abundant branching corals forming upward growing shoals at 30 m depth.

The Amirantes Bank, to the west of the Seychelles Bank, is the second major island group. It has ten islands and atolls and several shoals and submerged reefs. A total of 18 genera of scleractinian corals have been recorded (Stoddart, 1984a). The African Banks, described by Stoddart and Poore (1970d), are two sand cays with a total area of 0.04 sq. km on the north of the Bank, on the east side of the Amirante Ridge. North Island (275 x 90 m) and South Island (230 x 70 m) are scarcely above sea-level. To the south and west is a wide area of shoals and reef patches about 14 m deep, with a total area of 7.1 sq. km, the reef edge lying 450-800 m east of the cays. Remire (Eagle) is a small (80 ha) oval sandy island, 0.8 km in diameter, described by Stoddart and Poore (1970c). It lies on a small reef flat (1 sq. km) which extends 140-370 m from the shore on the north-west and south-east; there is littoral beachrock on the south and east and surrounding water depths are less than 35 m. D'Arros lies centrally on the Amirante Bank at 5°24'S, 53°18'E and is described by Salm (1977) and Stoddart and Coe (1979). It is an oval-shaped sand cay (1 x 1.9 km; 1.7 sq. km) on a patch reef which extends up to 1 km from the shore and has a total area of about 270 ha. There are emergent reef flats 250-400 m wide on the south side and a narrow reef flat, 75 m wide, on the north side. The reef slopes are gentle to the west and south and descend to 30 m after 1.4 km, but are more abrupt in the east where the 30 m isobath lies 100-300 m from the reef edge. There is no coral on the windward reef flats which are covered with mobile sediments but the leeward side has coral colonies and seagrasses. St Joseph lies 1 km east of D'Arros and is a small atoll about 4 x 6 km (22.5 sq. km) with several small islands on the broad reef flat (Stoddart *et al.*, 1979).

Poivre Island is on the east of the Amirantes Bank and has a shallow lagoon and reefs which are considered interesting. The Marie Louise Islands are near the southern end of the Bank but do not have particularly rich reefs (Salm, 1977). Desnoeufs is on the south of the Amirante Bank and has large number of rabbits, shearwaters *Puffinus* spp. and Sooty Terns *Sterna fuscata* (Piggott, 1961). The reefs are considered interesting (Salm, 1977). Desroches is a sand cay (5.25 x 1.1 km; 324 ha) on the windward rim of a slightly submerged atoll, 16 km east of the main Amirante Bank. The atoll is 19 x 21 km and the rim has average depths of 2-9 m but up to 18 m on the west (Stoddart and Poore, 1970b). There are no patch reefs within the lagoon and there is no information on the peripheral reef.

All the other outer islands of the Seychelles are on separate bases and many are small and privately owned. The Alphonse group lies on a separate bank south of the Amirante Bank. Alphonse is a sand cay of 450 acres (182 ha) on the rim of a circular atoll 2 mi. (3.2 km) across and is described by Piggott (1961). The lagoon is about 7 m deep and the external reef slope drops steeply into deep water. St Francois is described as an atoll by Piggott (1961) but there is no other information.

The Providence group is situated on Providence Bank. Providence (2.75 x 0.8 mi. (4.4 x 1.3 km); 2.3 sq. km) is in the north (9°14'S, 51°2'E) and has a reef platform on the west (Stoddart, 1967b). St Pierre is a circular, uplifted atoll, 0.75 mi. (1.2 km) in diameter and 1.7 sq. km in area, 19 mi. (30 km) south-west of Providence. Coastal cliffs rise to 10 m and the centre of the island is close to sea-level. Dunes are perched on the cliffs near blowholes and the reef rock is deeply intersected by caves. There is no fringing reef (Piggott, 1961; Stoddart, 1967b). Farquhar is an atoll (11 x 6.5 mi. (17.7 x 10.5 km); 172 sq. km) with several islands on the rim, mostly to the east or windward side. Its morphology is complex and unusual. The lagoon has a maximum depth of only 14.6 m and is crossed by a series of narrow ridges; there is a single entrance which is a narrow channel, 6-10 m deep, in the north. The bottom topography of the outer reefs is unusual, with large, mostly submerged spurs projecting from the southern side (Gardiner, 1907; Stoddart, 1967b; Stoddart and Poore, 1970a). Peripheral reef growth is continuing on the south-east side where the reefs extend over 2 km off shore. Seven genera of scleractinians have been described from Providence and Farquhar (Stoddart, 1984a).

Aldabra Atoll is described in a separate account. Cosmoledo Atoll (9°41'S, 47°35'E), consists of eight main islands located 110 km east of Aldabra (Bayne *et al.*, 1970b; Stoddart, 1967b). The lagoon is large, open and fairly shallow, with a maximum depth of 8 m. The atoll has an area of 152 sq. km (14.5 x 11.5 km), but only a small proportion (3.5 sq. km) supports land. The peripheral reef flat varies in width from 1 to 2.5 km. Coral growth is important in only a few places in the lagoon and there are few knolls and patches. No details are available for the outer slopes. Astove (10°6'S, 47°45'E) is an elevated atoll with a nearly continuous land rim, 35 km south of Cosmoledo (Bayne *et al.*, 1970a; Piggott, 1961; Stoddart, 1967b). It covers nearly 10 sq. km (4.6 x 2.8 km), about half of which is lagoon. This is mostly less than 0.5 m deep and has a restricted tidal range in which the diurnal rhythm is severely dampened by a superimposed lunar cycle. The rim rises to about 4-5 m above sea-level and forms low cliffs to seaward. The fringing reef is narrow, for the most part about 250 m wide. The reef slope is steep, especially to the west, and to the east there are deep erosional grooves. Assumption (3.7 x 1 mi. (6 x 1.6 km)) is an elevated reef island, 20 mi. (32 km) south of Aldabra formed of deeply dissected reef rock rising to 7 m above sea-level, with dunes on the east and south rising to nearly 30 m (Stoddart, 1967b; Stoddart *et al.*, 1970). No information is available on the reefs.

Over 850 fish species have been recorded (Salm, 1977). Hawksbill *Eretmochelys imbricata* and Green Turtles *Chelonia mydas* nest throughout the Seychelles, the Green Turtle population of between 1000 and 2500 being centred on Aldabra and Cosmoledo. Small numbers of Hawksbills nest on Providence, Cerf and Platt, an important population of about 80 nest on Cousin Island, approximately 600 nest on the granitic Seychelles, and larger numbers appear to nest in the Amirantes group. The Aldabra and Farquhar groups both have good numbers of foraging Hawksbill juveniles and adults, especially in the lagoons, with a few dozen nesting on Farquhar and Cosmoledo (Groombridge, 1982; Mortimer, 1985). The Coconut Crab *Birgus latro* still occurs on Aldabra, Cosmoledo and Farquar (IUCN/UNEP, 1984). Feare (1984) reviews the status of seabirds nesting throughout the Seychelles with special reference to the Amirantes group (ten, or possibly eleven, species, including a large population of Sooty Terns *Sterna fuscata*), Providence (five, or up to nine, species, including a large population of Sooty Terns), and the Aldabra group (twelve species, including Tropicbirds *Phaethon* spp., Boobies *Sula* spp., Frigatebirds *Fregata* spp., Terns *Sterna* spp., Brown Noddies *Anous stolidus* and White Terns *Gygis alba*). Mangroves are found on Curieuse, Praslin, La Digue and Silhouette and in the lagoons of some of the atolls such as Aldabra and Cosmoledo (Salm, 1978). Marine algae of Mahé are described by Mshigeni (1985).

**Reef Resources**

The Seychelles has a population of 63 000 people, of which 93% live on Mahé (40% in and around the capital city of Victoria) and the adjacent islands of Praslin and La Digue. From the 19th Century until the opening of the International Airport in 1971, the economy relied heavily on copra and cinnamon for exports, with local production of fruit and vegetables, supplemented by fish and imported rice. Copra production declined steadily after the early 1960s and has been replaced by tourism as the main source of foreign currency. As with many nations composed of small and scattered islands, the Seychelles now depend largely on their marine resources.

Considerable capital expenditure has taken place on Mahé, Praslin and La Digue to improve the infrastructure necessary for tourism. There is a large industry of glass-bottom boats, charter boat and dive tour operators, catering mainly for Europeans (Salm, 1978). Reef guides have been produced for divers and snorkellers (Salm, 1977; Vine, n.d.). The national parks and reserves, particularly St Anne, Cousin and Aride, are very important in the tourist industry. La Digue is a major tourist resort and a centre for water and reef-based recreational activities. Albatross Rocks, to the north of Felicité Island, are a popular diving site. Remire, on the Amirantes Bank, has a small guest house. The Marie Louise Islands are held to be the most beautiful of the Copra Islands but the reefs are not considered good for diving. The reefs of Desnoeufs are considered to provide interesting diving (Salm, 1977).

The fisheries potential around the granitic islands is substantial because of the extensive area of shallow water (UNEP, 1982; UN/Unesco/UNEP, 1982). The islands and atolls on the west and south of the Seychelles Bank generally have very small continental shelves, limited areas of shallow water, and correspondingly smaller fisheries potential. However, in general the fishery industry (mainly tuna) is being promoted and may overtake tourism as the major source of revenue. The potential for commercial utilisation of seaweeds on Mahé is discussed by Mshigeni (1985) and for a mother-of-pearl industry by Parkinson (1984).

**Disturbances and Deficiencies**

There was a large increase in the Crown-of-thorns Starfish *Acanthaster planci* population at Baie Chevalier on Praslin in the 1970s (Wilson, 1980), but the long term impact of this is not known.

Landfill and dredging may be the most serious threats to the reefs at present. The granitic character of the islands on the Seychelles Bank presents special problems for urban and residential development. Most of Mahé is too steep and rugged for agricultural and residential development; only about 1000 ha are cultivatable (UN/Unesco/UNEP, 1982) and the soils are relatively poor. One consequence of the lack of flat, easily usable land is that many parts of the shoreline have been filled in and several major land reclamation projects have recently been completed (Salm, 1978). The east coast of

Mahé, from the airport north and including North West Bay, is an area of intense development and has particularly suffered through the loss of mangroves, from reclamation projects for the airport, harbour construction and industry (IUCN/UNEP, 1984). Direct destruction of reefs due to dredging has been reported by Vine (1972). Praslin and La Digue have slightly better agricultural conditions and there is therefore less pressure on the coast. There is nevertheless a potential threat to the reefs from siltation due to soil run-off. The hillsides in several areas are scarred as a result of terracing and removal of hardwoods. In theory, all agricultural plots must be terraced and, after completion of a building, all property must be landscaped in order to control erosion, but no controls are required during construction work (Salm, 1978). Mangroves have been extensively cleared which may also lead to siltation.

On Mahé, raw sewage, supposedly treated, flows from the hotels into North West Bay and although there is no direct evidence of damage, in 1974/75 extensive patches of *Acropora* in Mare Anglaise in the Bay had black-line disease. Littering is also a problem here (Salm, 1978). Salm (1983) mentions that coral mining might be started which would lead to even more serious problems.

Currently, the local shallow water fisheries are having little impact on the reefs. However, spiny lobsters *Palinurus* have become scarce on shallower reefs as demand from hotels and restaurants is high. Corals and shells have been collected extensively and depletion is evident around St Anne and North West Bay on Mahé, Albatross Rocks and the western reefs of La Digue (Salm, 1978).

The more remote coral islands are less affected by tourism, development and other human activities. Many had guano deposits which were heavily mined in the last century, causing the loss of natural vegetation (Piggott, 1961). For example, early in this century Assumption was well wooded, but little of its original character remains and bird and turtle populations were decimated over the same period; Remire in the Amirantes has been similarly affected (Stoddart *et al.*, 1970; Stoddart and Poore, 1970c). Guano is reportedly still mined on Assumption and possibly on St Pierre (Salm, 1978). The Government is now encouraging agricultural development on some of these islands and is developing the infrastructure needed to manage islands spread over nearly one million square kilometres. Plans include a greater fisheries effort (IUCN/UNEP, 1984).

**Legislation and Management**

IUCN/UNEP (1984) and Salm (1978) list the various parts of the Seychelles legislation which relate to marine conservation, including the Control of the Removal of Sand and Gravel Ordinance 22 of 1964, the Beach Control Ordinance 13 of 1971 and the Control of Natural Resources of the Seabed and Subsoil Ordinance 16 of 1967. Fishing is regulated, dynamiting is prohibited and spearfishing has been illegal since 1968 (Polunin, 1974). Territorial waters are patrolled and legitimate fishing vessels are charged licence fees within the Seychelles Exclusive Economic Zone.

Turtle exploitation in the Seychelles has long been a problem. The Green Turtles Protection Regulations (SI 43/1976) and the Green Turtles Protection (Amendment) Regulations of 1977 used to prohibit the capture of females at any time and of males between November 1st and February 28th (the breeding season) and the Hawksbill Turtles (Protection) (Amendment) Regulations 1978 controlled the harvesting of Hawksbills. The Turtles (Protection) Regulations S.I. 115 of 1979 revokes these laws and provide protection for all marine turtles. Migratory species such as the Sooty Tern are protected.

The Conservation of Marine Shells Act 1981 bans the collection of shells from shell reserves except dead shells on the foreshore and bans the collection anywhere of the listed protected species; for other species there is a limit of 20 kg a day; the sale and purchase of unworked shells, and of unworked and worked shells of the protected species is prohibited and shells may not be exported other than for personal or non-commercial purposes; the use of explosives is prohibited within the reserves. This repeals the Protection of Shells Regulations (SI. 91/1969), the Protection of Shells Ordinance (Cap. 138) of 1965 and Proclamation 18 concerning shell exports. However this legislation is poorly enforced. The reserves are as follows:

- Mahé: from North-east Point to Anse Nord d'Est
- Mahé: from South-east Island to Pointe au Sel
- La Digue: from La Passe north to Cap Bayard River
- Praslin: from Anse Boudin east to Pointe Zanguilles

Local dive centres are reported to be helping to enforce legislation and control tourist activities. For example, in North West Bay, Mahé, the ban on spearfishing and a tight control on the removal of live specimens by SCUBA is considered to have had a noticeable effect on the reefs, which are still good in some areas despite heavy diver pressure. There is no comprehensive coastal zone management and each proposed shore development is considered on its own merit, although certain beaches on Mahé, Praslin and La Digue are designated as protected beaches. The entire coastlines of Cousin, Curieuse, St Anne, Cerf, Cachée, Long, Moyenne and Round Islands are reported by Salm (1978) to be protected, but details of this legislation are not known (it may concern the legislation for protected beaches).

The National Parks and Nature Conservancy Ordinance (1969) and its various amendments (Ordinance 7 of 1973, Statutory Instrument (S.I.) 95 of 1975, and Act 19 of 1982) and the National Parks and Nature Conservancy (Procedure for Designation of Areas) Regulations S.I. 110 of 1971 provide the basis for the network of National Parks and Reserves. Each separate reserve also has its own regulations published through the Official Government Gazette. The Seychelles National Environment Commission (SNEC) is derived from the National Parks and Nature Conservancy Commission created under the National Parks and Nature Conservancy Act (1969) and is the managing authority for the four designated types of protected area: Strict Natural Reserves, Special Reserves, National Parks and Areas of Outstanding Natural Beauty. The following include coral reefs:

- Baie Ternay Marine National Park
- Port Launay Marine National Park
- Curieuse Marine National Park
- St Anne Marine National Park

The Forestry and Conservation Division of the recently created Ministry of National Development is the main executive for conservation policy and is responsible for the creation and management of all protected areas except Aldabra, Cousin and Aride. Aldabra is administered by the Seychelles Island Foundation, Aride by the Royal Society for Nature Conservation and Cousin by the International Council for Bird Preservation (*see separate accounts*). Each protected area has a management plan, most of which have been approved by the Council of Ministers. As far as marine areas are concerned, the plans for Port Launay and Baie Ternay Parks have yet to be implemented due to lack of personnel, funds and equipment. There is a policy to find work for all fishermen who are deprived of traditional fishing grounds through the creation of marine parks, and fishing rights are only given to people who actually live within the park (IUCN/UNEP, 1984).

The following islands were declared Nature Reserves under the Wild Animals and Birds (Protection) Ordinance 1961 and the Wild Birds (Protection) Regulations 1966: Beacon (Ile Sèche), Booby (Ile aux Fous), Boudeuse, Etoile, King Ross (Lamperiaire), Les Mamelles, Cousin (*see separate account*) and Vache Marine (Government of Seychelles, 1971). The emphasis in these reserves is largely on the conservation of the species rather than of habitat. Early publications in conservation in the Seychelles include Polunin (1972) and Proctor (1970 and 1973).

**Recommendations**

In 1982, SNEC set up sub-commissions to produce reports covering topics such as pollution, legislation, education and National Parks, which will be used in structuring a National Conservation Strategy to replace the 1971 White Paper on the Conservation Policy of the Seychelles, which emphasized the protection of sites of natural beauty and neglected less attractive but equally important sites such as mangroves. Further protection is required for reefs and mangroves and buffer zones may be necessary for the Marine Parks (IUCN/UNEP, 1984). IUCN/UNEP (1984), Salm (1978) and Stoddart and Ferrari (1983) all emphasize the need for training of personnel for wardening and policing of protected areas and for educational projects for local people and visitors. Salm (1978) provides detailed recommendations for further research and survey work.

Since the 1970s, a number of recommendations have been made for the marine environment (Government of Seychelles, 1971; IUCN/UNEP, 1984; Robertson, 1972; Salm, 1978). The following areas bordering the coast have been recommended for protection:

1. The proposed La Digue National Park will include the north-east coastal area from Anse Severe southwards to Anse Caiman (Government of Seychelles, 1971; IUCN/UNEP, 1984). An area of 8.3 ha on the western plateau of La Digue was designated the La Digue Veuve Nature Reserve in 1979 (described in IUCN, 1987).
2. Desnoeufs Island, proposed as a Special Reserve to protect colonies of Sooty Terns and Noddy Terns; eggs are traditionally collected but it is suggested that quotas should be reduced and management improved (Government of Seychelles, 1971; IUCN/UNEP, 1984)
3. The African Banks in the Amirantes are uninhabited and belong to the Seychelles Government; they are recommended as Special Reserves for nesting Sooty Terns and Noddies. Salm (1977) considers the reefs on the west of the island to be very vulnerable to anchor damage from visiting boats.
4. Bird Island (Ile aux Vaches)
5. Récif Island
6. Frégate
7. Felicité
8. Cosmoledo
9. Cousine
10. Albatross Rocks/Cocos Island (proposed as a Marine National Park); these are large rocks surrounded by spectacular reefs. The Marine National Park has been approved by the Seychelles National Environment Commission and only needs to go to the council of ministers and public representations before becoming official.

(4) to (9) are proposed as Special Reserves for their bird and/or turtle populations by Government of Seychelles (1971) and IUCN/UNEP (1984). Cosmoledo and Desnoeufs are already being administered by the Island Development Corporation. Bird Island, Frégate and Cousine, adjacent to Cousin Island, are owned privately at present. The other islands are government owned and would be administered by the Conservation Section of the Wildlife Department.

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## ALDABRA ATOLL SPECIAL RESERVE

**Geographical Location** North of the Mozambique channel, 640 km east of the coast of Africa and 420 km north-west of Madagascar; 9°25'S, 46°25'E.

**Area, Depth, Altitude** 34 x 14.5 km; total area 35 000 ha (18 800 ha land, 2000 ha mangrove, 14 200 ha sea); the lagoon (150 sq. km) is on average 2-3 m deep at low tide although the Main Channel is 24 m deep at the entrance; sand dunes along the south coast reach 18 m. The Reserve extends 1 km beyond high water mark.

**Land Tenure** In 1967 the Royal Society acquired the lease to the islands and was succeeded in 1980 by the Seychelles Islands Foundation, a charitable trust established under the Seychelles Islands Foundation Decree, 1979.

**Physical Features** Stoddart (1967a) gives a detailed description of Aldabra, a raised atoll elevated a few metres above present sea-level. Much of the coastline consists of deeply undercut limestone cliffs and a broad intertidal reef flat. On the southern windward coast, the cliffs are topped by a perched beach and sand dunes. The entire atoll is surrounded by an outer reef whose slopes drop to over 50 m depth within 100 m of the islands and more steeply still on the north and western sides. There are four main islands in the lagoon, several of which connect with the rim at low tides. The lagoon is shallow but where the Main Channel enters, depths of 6-10 m are found up to 6 km from the entrance. The lagoon shores are either undercut reef limestone or fringed with mangroves. Erosion of the former is taking place, such that the lagoon is expanding at the expense of the land area. Geomorphological processes have produced a varied topography on land, which is mostly rugged but provides a wide variety of habitats. Much of the ground is pitted and covered by a dense thicket of shrubs and there is little freshwater. Only at the eastern end, on upraised lagoonal sediments, is the surface more continuous with freshwater pools and open woodland. Aldabra has the largest land area of the Seychelles atolls by a substantial margin, which has had important consequences in the development of an indigenous fauna and flora.

The climate is semi-arid. The annual rainfall of about 700 mm occurs mostly between November to April, but may be as low as 500 mm, or as high as 1200 mm on various parts of the atoll (Stoddart, 1984b). For the rest of the year, including the period of the strong south-east trades, the atoll receives little rain. The tidal range is about 2.6 m on seaward slopes and currents can reach 6 m/sec. in the main channel at spring-tides. Because of the topography of the channels into the lagoon and their small cross section, there is a substantial lag in lagoonal tides, such that on the outer reefs the tide may have begun to fall while water is still flowing into the lagoon. Tidal regimes are described by Pugh and Rayner (1981).

**Reef Structure and Corals** Stoddart (1967a) describes the emergent reef features and the reef flat in some detail. Barnes *et al.* (1970 and 1971) studied the sublittoral but the biology and ecology of the deeper parts of the reef have been largely neglected. Six coral zones were described (Barnes *et al.*, 1971); the ahermatypic *Dendrophyllia* is found in shallower water, almost to low water mark in the passes. Brander *et al.* (1971) describe the reefs at Passe du Bois and Settlement.

Most of the lagoon floor is covered with carbonate sand and mud overlying an irregular rock floor. Living corals are confined to the region around the channel entrances. To seaward, the reef flat averages 200-300 m in width on the north and south coasts and up to 500 m on the sheltered west coast. It is an erosional feature of planed reef rock with a thin cover of sand and *Cymodocea*. It is not a primary reef flat formed by contemporary reef growth and it has few corals (Stoddart, 1967a).

Several transects on the seaward reefs around the island were made by Barnes *et al.* (1971). These showed that hermatypic growth is most abundant at 10-25 m depth, although isolated colonies occur between the high water mark and 55 m depth or more. Four categories of reef, based on different degrees of exposure, were proposed by Barnes *et al.* (1971). The most exposed areas had no reef flat or reef ridge but the reef sloped gradually down from the raised reef to 30 m depth over a distance of at least 100 m. This type of reef was found only on the east of the atoll and no hermatypic corals were present, the substrate being composed of compacted coral sand and aggregations of calcareous red algae. The south of the atoll is less exposed and the reef has a reef flat, but with no marked ridge; there are large areas of dead coral.

The third type of reef is found in the north, and it slopes from a wide reef flat and a marked reef ridge. Hermatypic corals are abundant and the deep reef slope is characterized at 25 m depth by bastions of coral rock, protruding from the reef front, with steep seaward faces which drop to about 45 m. The fourth type is found in the most sheltered, westerly-facing areas and drops more steeply than the other reefs, from a wide reef flat and a marked reef ridge. On these slopes hermatypic growth is most abundant.

The corals of the atoll are listed by Barnes *et al.* (1970 and 1971) and updated by Rosen (1979). Forty-seven scleractinian genera (44 hermatypes) have been recorded (Stoddart, 1984a).

**Noteworthy Fauna and Flora** Mangroves and seagrass beds are found in lagoonal areas. The terrestrial flora is exceptionally rich and is briefly described in IUCN (1987). Much of the fauna was originally shared with neighbouring islands where it is now extinct as a result of human activities. Aldabra therefore has a number of endemic terrestrial species, the world's largest population of Giant Tortoises *Geochelone gigantea* (over 150 000 individuals) and 13 species of terrestrial birds including the endangered Aldabra Warbler *Nesillas aldabranus* and the Aldabran Flightless Rail *Dryolimnas cuvieri*. The colonies of Red-footed Boobies *Sula sula* and Frigatebirds *Fregata* spp. are the largest in the Western Indian Ocean; there are also major populations of Lesser Noddies *Anous tenuirostris*, Red-tailed Tropicbirds *Phaethon rubricauda* and a small permanent population of flamingoes *Phoenicopterus ruber*. Feare (1984) lists twelve breeding species of seabirds. The unexploited nature of the surrounding waters has meant that molluscs and large fish are abundant (Stoddart and Ferrari, 1983). About 1000 Green Turtles *Chelonia mydas* nest annually on the beaches. Hawksbill Turtles *Eretmochelys imbricata* forage around the atoll, especially in the lagoon, and may nest in small numbers (Groombridge, 1982).

**Scientific Importance and Research** A fully equipped research station was opened on Ile Picard by the Royal Society in 1971 and is maintained by the Seychelles Islands Foundation. The Seychelles Government maintains a meteorological station. Over 200 papers have been published on the terrestrial and marine environments. The terrestrial ecology of the atoll has been extensively studied and Aldabra is probably the best known of any Indian Ocean atoll. The marine environment is less well known but a programme of marine research is being set up (Stoddart and Ferrari, 1983).

**Economic Value and Social Benefits** Development is restricted to small-scale tourism and limited exploitation of some natural resources. There is a limited amount of fishing as Seychelles workers supplement their income by selling salt fish to Mahé. Large-scale tourism is not thought to be financially practicable. Stoddart and Morris (1980) outline areas where commercial exploitation might be possible.

**Disturbance or Deficiencies** Past exploitation of mangroves, turtles, fish and tortoises appears to have done no irreparable damage and the populations have all recovered. Rats, cats and goats have been introduced and have become established, threatening the long-term survival of some of the terrestrial species. The difficulties of effective patrolling of the atoll threatens the integrity of the Reserve, the maintenance of which is dependent on the ability of the Foundation to support adequate wardening staff and a functioning research station. A shortage of funds is probably the main threat (IUCN, 1987).

**Legal Protection** Aldabra was designated as a Special Reserve on 9 September 1981 under the National Parks and Nature Conservancy Act, 1971. The Aldabra Special Reserve Regulations 1981 give the Seychelles Islands Foundation wide powers to control entry into and behaviour within the Reserve. The Reserve is defined as the atoll, the bed of the sea in the lagoon and the sea and sea floor within 1 km of the high water mark. Stoddart and Ferrari (1983) describe early conservation measures on the island (which was first designated as a Strict Nature Reserve in 1976). The atoll was accepted as a World Heritage Site in 1982 (IUCN, 1987).

**Management** The atoll is managed by four subcommittees under the Seychelles Island Foundation which was set up primarily for the management and conservation of Aldabra. A management plan has been accepted by the Seychelles Government (Stoddart and Morris, 1980). Further details are given in IUCN (1987). The Director of the Research Station is the Warden. Hambler (1985) describes current conservation issues on the island.

**Recommendations** The present requirement is to maintain the policy of minimum human interference while continuing the research and monitoring programme. The management plan (Stoddart and Morris, 1980) gives recommendations for the preservation of the scientific value of Aldabra, while indicating where limited commercial exploitation would be possible. There is a need to monitor the marine biota, particularly if exploitation takes place. Deep sea sport fishing or exploitation of predatory fish and marine curios, apart from empty shells, is not considered appropriate. Specialist or naturalist tourism could perhaps be developed. Recommendations for wardening and surveillance are given.

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## ARIDE ISLAND SPECIAL RESERVE

**Geographical Location** The northernmost granitic island of the Seychelles group, 9 km NNE of Praslin; 4°08'S, 55°40'E.

**Area, Depth, Altitude** Island is 70 ha, rising to 134 m. The coral reefs around the island extend 200 m from shore.

**Land Tenure** Owned since 1973 by the Royal Society for Nature Conservation (formerly Society for the Promotion of Nature Reserves).

**Physical Features** Ninety percent of the crescent-shaped island is occupied by a rugged hill. The remainder is a coastal plain, not much higher than 4 m above high tide level. A general description is given in Warman and Todd (1984).

**Reef Structure and Corals** The island is surrounded by fairly exposed fringing reefs with a notable spur and groove formation near the landing stage; there are reported to be fine stands of *Acropora*. No further details are available (IUCN/UNEP, 1984).

**Noteworthy Fauna and Flora** Vegetation on the island is described in IUCN (1987) and Warman and Todd (1984). The island has over a million pairs of seabirds of about 11 species including the world's largest colonies of Lesser Noddies *Anous tenuirostris* and Roseate Terns *Sterna dougallii*. It is the only place in the granitic Seychelles where the Red-tailed Tropicbird *Phaeton rubricauda* breeds. Other birds are briefly described in IUCN (1987) and Warman and Todd (1984). A small number of Hawksbill Turtles *Eretmochelys imbricata* breed on the beach. There is little information on the marine biota but the area is noted for a particularly brightly coloured variety of surgeonfish *Acanthurus* sp. (IUCN/UNEP, 1984).

**Scientific Importance and Research** Studies have been carried out on the terrestrial vegetation and seabird colonies and are summarized by IUCN/UNEP (1984).

**Economic Value and Social Benefits** The island is cultivated around the bay and there are a few permanent inhabitants. Visitors come to see the birds and considerable revenue is generated through tourism. Bathing is permitted although currents are considered dangerous. Snorkelling and diving are considered excellent (Salm, 1977).

**Disturbance or Deficiencies** The island is free from introduced mammals which accounts for the large seabird colonies. The reefs are reported to be undamaged.

**Legal Protection** Designated a Special Reserve, 17 June 1975 by the National Parks and Nature Conservancy (Designation of Special Reserve) (Aride) Order, 1975, S.I. 99. The Aride Island Special Reserve Regulations 1979, S.I. 92, define what is allowable within the reserve. Also listed as a protected breeding site under the Turtle Protection Act; turtles may not be hunted up to 1000 m from the high water mark.

**Management** Details are given in the management plan (Anon., 1978). The Beach and Reef zones are covered by Special Regulations which prohibit collection of lobster, shells and corals, protect turtles, require that boats should only anchor in certain defined areas, that the reefs within 200 m of the shoreline should only be fished when weather conditions preclude the use of other areas, and that swimming should be restricted to certain marked areas. There are a number of reserve staff including a boatman (IUCN, 1987) and the Reserve is administered by the Aride Island Local Management Committee. The island is closed between May and September.

**Recommendations** It is intended to declare an area of up to 200 or 300 m from the shore as a Marine National Park. Salm (1978) recommended an extension of 200 m. This has been approved by the Seychelles National Environment Commission and only needs to go to the Council of Ministers and public representations before becoming official (IUCN/UNEP, 1984). A survey of the marine environment is required (Heaton *in litt.*, 6.2.87).

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## BAIE TERNAY AND PORT LAUNAY MARINE NATIONAL PARKS

**Geographical Location** Baie Ternay is a sheltered bay on the extreme western tip of Mahé (4°38'S, 55°22'E); Port Launay is a cove on the other side of Ternay Bluff from Baie Ternay (4°39'S, 55°23'E); the two bays form a natural marine extension of the Morne Seychellois National Park.

**Area, Depth, Altitude** Baie Ternay is 80 ha; max. depth 37 m; Port Launay is 158 ha; max. depth 20 m.

**Land Tenure** Government-owned.

**Physical Features** Port Launay is a beautiful sheltered cove with a sandy beach and rocky shores at either end. Visibility is poor (3-4 m) but improves near the mouth of the cove (Salm, 1977). Baie Ternay has a shallow lagoon (up to 25 m deep), approximately 800 m wide, separating the continuous fringing reef at the head of the bay from the shore.

The climate is determined by the strong dry winds of the south-east monsoon, which blow from May to October, and the erratic north-west monsoon, which alternates between periods of calm, squalls and torrential rains, and blows from December to March. November and April are the transitory months. The mean annual temperature varies from 24° to 30°C and relative humidity is always high, between 75% and 80%.

**Reef Structure and Corals** Pillai *et al.* (1973) have described some of the corals in this area. Salm (1977) gives a brief description of the reefs. Fringing reefs are found at either end of the beach at Port Launay and are characteristic of areas of calm sea and erratic temperature and salinity. The back-reef zones are shallow and covered with *Turbinaria*. Reef development is not extensive and living corals are few. *Porites* forms the dead platform. The reef at Baie Ternay is grooved and cut by numerous surge channels at the head of the bay and is considered to be richer than that at Port Launay. The deeper reefs fringing the northern and southern rocky headlands are in very good condition but are predominantly soft corals on dead coral (Salm, 1977; Wilson, 1980).

**Noteworthy Fauna and Flora** Hawksbill Turtles *Eretmochelys imbricata* are present. Mangroves fringe the shore of Port Launay and are the habitat of the Seychelles Blue Pigeon *Alectroenus pulcherrima*. Fish are particularly abundant (Salm, 1977). Marine algae are briefly described by Mshigeni (1985).

**Scientific Importance and Research** A group from Galway University has carried out a general survey of Baie Ternay. There are no research facilities. Salm (1978) considers the alcyonarian communities in Baie Ternay to be the best on Mahé.

**Economic Value and Social Benefits** There is some fishing with handlines and traps and some seine netting for mackerel by National Youth Service staff and students. Port Launay and Baie Ternay are among the few sites where bait fish can be taken for the tuna industry. Both areas are popular for bathing, snorkelling and swimming, being easily accessible from Beau Vallon. Port Launay is a popular anchorage. Baie Ternay is also used by tourists and there is a glass-bottomed boat (IUCN/UNEP, 1984).

**Disturbance or Deficiencies** *Acanthaster planci* is present in both bays but no damage has been reported (Wilson, 1980). There has been some poaching of corals, shells and Hawksbill Turtles (although numbers taken within the Park are lower than those taken without) and overcollection of shells is evident (Salm, 1978). The first National Youth Service camp was established at Port Launay and in 1983 the second and largest one was established at Baie Ternay; these have effectively closed the area to the general public although there is still some tourism. The treated sewage from the settlement is discharged into the bay; the precise impact of this has yet to be assessed. Some of the mangroves have been reclaimed. Both bays are surrounded by the Morne Seychellois National Park which should afford them some protection.

**Legal Protection** Baie Ternay was designated under the Baie Ternay Marine National Park (Designation) Order, S.I. 54, 1979 and Port Launay was designated under the Port Launay Marine National Park (Designation) Order, S.I. 56, 1979. Both areas have been declared fishing reserves under the Fisheries Act S.I. 51 of 1962. Bait fishing and fishing by residents is permitted. Fishing with nets is restricted to daylight hours only with an encircling net and only certain species may be caught. There are additional restrictions on methods used (Wilson, 1980). Turtles may not be disturbed (Mortimer, 1985). The Port Launay Marine National Park Regulations 1981 prohibit damage to sandbanks, reefs, rocks or areas of sea-shore or foreshore and the killing, capturing or damaging of wildlife or the removal of material from the seabed.

**Management** A draft management plan exists for both areas but has not been enforced (Wilson, 1980). The Park boundaries exclude the beaches in order to allow recreational activities to continue. Lack of trained personnel, equipment and houses has meant that there is no enforcement of Park regulations.

**Recommendations** It has been suggested that the beaches should be included in the Parks, that provisions for recreation be developed (Salm, 1977), that tourism be limited to Baie Ternay and that even here its development should be restricted on account of the small size of the area. Environmental education should be the main activity in the Port Launay Marine National Park and the adjacent proposed La Plaine Swamp Special Reserve; educational activities should be centred on the National Youth Service Camp. Fishing licences should be issued to residents and a catch quota introduced. Wilson (1980) lists a number of suggested research projects for the area.

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## BIRD AND DENNIS ISLANDS

**Geographical Location** Northern edge of the Seychelles Bank; Bird Island is at 3°43'S, 55°13'E; Dennis is 25 mi. (40 km) to the west at 3°48'S, 55°40'S.

**Area, Depth, Altitude** Bird Island 1800 x 1000 yds (1646 x 914 m), max. alt. of about 14 ft (4.3 m); Dennis 2000 x 1380 m, max. alt. 14 ft (4.3 m).

**Land Tenure** Bird Island is privetely owned; Dennis Island is Government owned.

**Physical Features** The islands are the only sand cays on the Seychelles Bank and are formed entirely of calcareous sand with an unstable sandy shore. Dennis Island has small cliffs in the south-west formed from eroded sandstone. Prevailing winds are from the south-east, as is evidenced by the location of the broad reef flats around the islands. Rainfall is about 2000 mm a year on Bird, and 1730 mm on Dennis. Tidal range is about 1.2 m (Fryer, 1910).

**Reef Structure and Corals** Data on the reef flats come from Fryer (1910) and Stoddart and Fosberg (1981); Salm (1977) provides a popular account. On Bird Island, there is no true reef rock to act as a basis for sand accumulation and annual changes in the extent of the beaches are evident (Fryer, 1910). Reef flat is most developed to the south-east of both islands where it extends outwards for several hundred metres and is covered with sand and *Cymodocea*. There is a poorly defined boulder zone. A well defined buttress zone on the seaward face has a little live coral mainly *Millepora*, with some *Heliopora, Pocillopora* and *Stylophora*. The whole reef is very sandy, especially in the north-east. On Dennis Island the reef flat is also covered with sand and there is a poorly developed boulder and buttress zones. From the reef flats, the reef slopes descend to 10-20 m and, in some areas close to the islands, there is a vertical drop-off from 18 to over 100 m off the edge of the Seychelles Bank (Salm, 1977). There is no information on the coral fauna of the reef slopes.

**Noteworthy Fauna and Flora** Fryer (1910) briefly describes the vegetation and the terrestrial fauna of the islands which are poor. Dennis Island is largely given over to a coconut plantation. Bird Island has an enormous colony of Sooty Terns *Sterna fuscata* and a colony of Brown Noddies *Anous stolidus* (Feare, 1984). The Dugong *Dugong dugon* used to be found in the waters surrounding Bird Island (originally called Ile aux Vaches after the "vaches marines") but was locally extinct at the time of Fryer's visit. Green Turtles *Chelonia mydas* were once abundant but are now scarce. There are a few introduced Giant Tortoises *Geochelone gigantea* on Dennis.

**Scientific Importance and Research** No information.

**Economic Value and Social Benefits** At the time of Fryer's visit, the islands were visited for egg collecting between June and August. The islands provide the best diving in the granitic group and there is a small hotel on Bird Island, the Sooty Tern colony providing a popular attraction (Salm, 1977).

**Disturbance or Deficiencies** None are known for the reefs, although the islands have been subjected to some phosphate mining and the natural vegetation of Dennis Island has been destroyed by the coconut plantation.

**Legal Protection** None.

**Management** No information.

**Recommendations** The northern part of Bird Island has been recommended for protection as a Special Reserve (Government of Seychelles, 1971).

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## COUSIN ISLAND SPECIAL RESERVE

**Geographical Location** About 4 km south-west of Miller's Point on Praslin on the Seychelles Bank; 4°20'S, 55°40'E.

**Area, Depth, Altitude** Island is 27 ha; max. alt. 58 m; the Reserve extends 400 m seawards of high water mark; maximum depth within a 10 mi. (16 km) radius is 55 m; the edge of the Seychelles Bank and deeper water lies 48 km to the east.

**Land Tenure** In 1968 Cousin Island was purchased by the Society for the Promotion of Nature Reserve (now the Royal Society for Nature Conservation) and is held in trust for the International Council for Bird Preservation.

**Physical Features** The island is central in the group of granitic islands and is relatively sheltered, mainly by Praslin. It is approximately rectangular in shape, and about 80% consists of a flat plain of phosphate sandstone. There is a single granitic hill, forested on the north and east slopes, and rocky and barren on the south and west slopes which drop straight to the shore. Roche Cannon, a group of rocks, lies 200-300 m off the north-west point linked with the main island by a natural stony causeway which is exposed at low tide. A beach runs from the most westerly point to the southerly point, Anse Fregate, and there are sandy beaches on the north coast. During the south-east trades the east beach is eroded to expose the underlying beach rock and the north beach develops a beach flat up to 100 m wide. In the north-west monsoon the north beach is eroded and the east beach is restored. This has an important effect on sublittoral habitats where scouring occurs. The only freshwater is a small seasonal rivulet on the northern side of the hill. A description of the island and its climate is given in the management plan (Diamond, 1980; Garnett, 1985; ICBP, in prep.) and in Diamond (1985).

**Reef Structure and Corals** A fringing reef surrounds the island, extending out on average about 200 m. This was surveyed by Frazier and Polunin (1973) in the course of an ichthyological study and a detailed description is given. Despite its small size, the island has a great variety of reef forms. Although vertical zonation is not well developed, there is wide lateral variation due to differences in water movement and substrate. The *Acropora* assemblage is the main coral community. *Millepora* is common or even dominant in shallow inshore areas with much wave action; *Pocillopora* and to some extent *Stylophora* occur to seaward in exposed areas; *Acropora* occurs on exposed reefs but below the zone of strongest wave action; *Porites* is found at the base of reef slopes.

The north-east reef has a reef flat of scoured reef rock. The reef slope is one of the richest coral areas around the island, with about 90% living cover. *Acropora* is dominant and other branching forms are found.

On the east reef, *Millepora* and soft corals are commoner on the reef flat, and thick tufts of filamentous green algae appear. Erosional pits caused by the scouring sand are common, sometimes up to 2 m deep and 10 sq. m in area. At the southern end ridges of coral rubble rise 2-3 m above the reef flat. The reef slope descends at about 45-60° to a sandy floor at about 12 m depth and has 70% cover of *Acropora*, although other corals are common. Sand, rubble ridges and channels are frequent features of the sublittoral in this area.

The south reef (Anse Fregate) has a narrower reef flat which drops sharply to an area of broken slabs of reef material at about 4 m. The slabs are evidently cut from the platform and have no particular orientation. Cover by hard corals is only 5%. Conspicuous ridges of coral running parallel to each other and perpendicular to the edge of the reef flat, extend seaward for 150 m. *Acropora* and soft corals are abundant on the ridges and the total cover by the two groups reaches 75%; it is much less in the valleys between. There is a bank of coral 300-400 m off shore on the south-west coast but this has not been investigated.

The north-west reef (Roche Canon) has an unusual outcrop of granite. Coral cover is less than 5% and is mainly *Pocillopora*. In deeper water there are ridges of coral which appear to be undercut to some degree and are less regular in appearance than those on the south reef. *Porites* is abundant in deeper water and among coral rubble. The west reef (Passe Vacoa) is also described.

**Noteworthy Fauna and Flora** The island is well known for its bird fauna which includes White Terns *Gygis alba*, Lesser Noddy Terns *Anous tenuirostris*, White-tailed Tropicbirds *Phaethon lepturus*, Frigatebirds *Fregata* spp., some terrestrial Seychelles endemics and Giant Tortoises *Geochelone gigantea*. Terrestrial fauna is described in Diamond (1975 and 1980; ICBP in prep.) and summarised in IUCN (1987) and IUCN/UNEP (1984). Frazier and Polunin (1973) listed 233 species of fish and thought that there might be as many as 300; the richest areas for fish are in the south and north-west. Cousin Island is one of the main breeding areas north of Madagascar for Hawksbill Turtles *Eretmochelys imbricata*; the Green Turtle *Chelonia mydas* breeds occasionally (Brooke and Garnett, 1983; Diamond, 1975 and 1980; Phillips and Wood, 1983; Wood, 1986). There are substantial areas of mangrove swamp between Anse Fregate and Ilot. Further details of the fauna and flora of the island are given in Diamond (1985) and ICBP (in prep.).

**Scientific Importance and Research** Most scientific work has concerned the birds of the island and there is an extensive publications list which is available from ICBP; past research is summarised in ICBP (in prep.). Considerable work has also been carried out on turtles. There is a laboratory for 2-3 scientists (IUCN/UNEP, 1984). Frazier and Polunin (1973) considered the Cousin reefs to be ideal for research.

**Economic Value and Social Benefits** The island is uninhabited apart from the Reserve staff but is open to visitors who are brought over from Praslin in the staff boat and are given a guided tour. There is no overnight accomodation. Considerable revenue is generated from tourism, with about 4000 visitors a year. There is some fishing on the surrounding reefs, but in general this has declined (ICBP, in prep.).

**Disturbance or Deficiencies** Prior to 1968 the island was a coconut plantation and the natural vegetation was considerably altered. At that time the turtles were exploited in the surrounding waters and shells were taken from the reefs. Robertson (1972) found evidence of extensive shelling and damage to corals from anchors, but this has now ceased (Diamond, 1985). Hawksbill Turtles are still taken illegally (ICBP, in prep.; IUCN/UNEP, 1984) although improved enforcement has been a deterrent.

**Legal Protection** The island was first established as a nature reserve under the Wild Animals and Birds Protection Ordinance, 1966. Subsequently the Special Reserve was gazetted under the National Parks and Nature Conservancy (Designation of Special Reserves)(Cousin Island) Order, 1975 and is administered through the Cousin Island Special Reserve Regulations, S.I. 93, 1979. Turtles are protected, out to 1 km from shore, under the Turtle Act which lists Cousin Island as a protected breeding site. Collection of marine organisms is prohibited and since the Reserve boundaries extend to 400 m beyond high water mark, the reefs are protected (Diamond, 1985; ICBP, in prep.).

**Management** Managed by the International Council for Bird Preservation who provide a warden and some assistants. Details of the management strategy are given in the management plan (Diamond, 1975) and subsequent revisions (Diamond, 1980; Garnett, 1985; ICBP, in prep.). There is no zoning strategy but visitors are not allowed in dense bird colonies. There are facilities for the half dozen staff and regular beach patrols are carried out, reinforced by the Curieuse Patrol and Praslin Police to protect the Hawksbill from poaching (IUCN/UNEP, 1984). A certain amount of fishing is tolerated within the reserve but in the last few years local fishermen have agreed to fish elsewhere and the only fish caught now are for consumption by island staff (ICBP, in prep.).

**Recommendations** It is recommended that the present anchorages are maintained as they are areas of neglible coral growth. A system of permanent mooring buoys should be established, possibly one at Passe Vacoa, one off the north boat shed and one off the south boat shed. Visiting boats should be strongly discouraged from dumping their rubbish in the sea (Salm, 1978). Cousine is a privately owned island adjacent to Cousin which was recommended for designation as a Reserve (Government of Seychelles, 1971); it is at present privately owned but could eventually be run as a single unit with Cousin Island (IUCN/UNEP, 1984).

## CURIEUSE MARINE NATIONAL PARK

**Geographical Location** Curieuse Island and surrounding waters including the channel between the island and the north-eastern coastline of Praslin, from Chevalier Point in the west to Pointe Zanguilles in the east up to high water mark, and the outlying islets of St Pierre in the south-west; 4°16'-4°18'S, 55°43'E.

**Area, Depth, Altitude** Total area 1370 ha including 283 ha of land (Curieuse); 30 m below sea-level to 172 m.

**Land Tenure** Government owned; on Praslin the land around Anse Petit Coeur and the two headlands are private property (Salm, 1977).

**Physical Features** Curieuse is an irregularly-shaped, rugged, granitic island. The surrounding area includes shallow reefs exposed at low tide, a drop-off at 30 m depth, algal reef flats, mangrove swamp, intertidal rocky shore and sandy beaches. Anse Volbert, which is on Praslin but is close to the south-east corner of the Reserve, has a long white beach and shallow lagoon. The Iles St Pierre are rocks rising 8 m from the sandy bottom opposite Anse Volbert.

**Reef Structure and Corals** Reefs fringe the south-eastern arm of Curieuse almost continually and are exposed at low tide. Much of the coral is dead, especially in the lower fore-reef region. There is a deeply grooved surf zone but no distinct reef front. The fore-reef slope has largely dead corals particularly in deeper water, which is a common feature of many Seychelles reefs. There is a drop-off to 30 m depth (IUCN/UNEP, 1984; Salm, 1977). On Praslin, the short beach and eastern arm of Anse Petit Coeur are flanked by a small fringing reef and there is a boulder reef off the headland (Salm, 1977). Coral growth is particularly good around Iles St Pierre, Point Chevalier in the west and Anse Petit Coeur on the west side of Pointe Zanguilles on Praslin.

**Noteworthy Fauna and Flora** The island's fauna including birds and reptiles, is described by IUCN (1987). Giant Tortoises *Geochelone gigantea* are being introduced from Aldabra so that visitors can see them. About 20-40 Hawksbill Turtles *Eretmochelys imbricata* nest on the beaches. Curieuse is one of the two islands where the Coco-de-mer *Lodoicea maldivica* grows naturally. There is a diverse patch of mangrove swamp; additional information on vegetation is given in IUCN (1987). The mollusc fauna is of interest to shell collectors. Reef fish are reported to be abundant and varied.

**Scientific Importance and Research** A tagging programme for the Hawksbill Turtle is underway and there have been some studies on the terrestrial fauna (IUCN/UNEP, 1984; Mortimer, 1985).

**Economic Value and Social Benefits** The island is inhabited and cultivated. Tourism is being promoted in an effort to provide income for the Seychelles Island Foundation. Boats and snorkelling or diving equipment can be hired from the Paradise Hotel at Anse Volbert on Praslin. Baie la Raie, Anse St Jose and Anse Possession are used as anchorages.

**Disturbance or Deficiencies** Poaching of Hawksbill Turtles continues. There are government schemes to exploit the takamaka trees and drain the marshes of the island. The island is badly burnt and eroded but the reefs are thought to be in good condition. The *Acropora* on the reef at Anse Petit Coeur has died but has been settled by new colonies (Salm, 1978); much of the coral on the south-east fringing reef of Curieuse is also dead. The island was once well known for the abundant molluscs and crustaceans in the surrounding waters but these have declined (IUCN/UNEP, 1984).

**Legal Protection** Declared a Marine National Park under the Curieuse Marine National Park (Designation) Order of 1979, S.I. 55, under the National Parks and Nature Conservancy Act, 1971. Protective regulations under this act have been drafted and will be introduced when designation is complete. Fishing by traditional methods is to be permitted (Wilson, 1979). The island is also listed as a protected turtle nesting site under the Turtle Protection Act; turtles may therefore not be caught within 1000 m of high water mark.

**Management** Administered by the Conservation Division of the Ministry of National Development. Details are given in the management plan (Wilson, 1979). The terrestrial area is divided into zones for conservation, soil conservation, forestry, agriculture and tourism. There are two designated swimming areas, at Anse Petit Coeur, which can only be approached from the sea, and from Mandarin, around Figaro and into the southern part of Baie la Raie which can be approached from land or sea. The remaining marine area is called the background marine zone; mangroves are considered as terrestrial wetlands for the purpose of management.

**Recommendations** Wilson (1979) gives detailed recommendations for improved management of the reserve. It is not known how many of these have been followed up. Resident fishermen should be licensed, and sport, commercial, spear, line, octopus, lobster and turtle fishing should be banned in the park. The reefs at Anse Petit Coeur, Mandarin and Baie la Raie should be demarcated with buoys and fixed moorings provided for small craft. The only permitted powered vessels should be glass bottomed boats. There is a proposal to establish an information centre and a chalet-style hotel on the island.

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## ST ANNE MARINE NATIONAL PARK

**Geographical Location** About 5 km east of Victoria, Mahé; includes the reefs and waters surrounding six granitic islands, of which St Anne is the largest; Iles aux Cerfs, Ile Long, Round Island and Ile Moyenne lie between St Anne and Mahé; Ile Cachée lies to the south of the group; 4°35'S, 55°30'E.

**Area, Depth, Altitude** 1423 ha; maximum depths are 30 m in the St Anne channel and the Park extends to the summit of St Anne, at 250 m.

**Land Tenure** St Anne, Round and Long Islands are government owned; Moyenne, Cerf and Cachée are privately owned.

**Physical Features** The six islands are granitic and rugged. There is a great diversity of habitats including reefs, coral encrusted granite boulders, sandflats and sandy beaches (IUCN, 1987). Fairly extensive beds of seagrass are found among some of the dead reefs. Visibility fluctuates and is often not very good although it improves at Grand Rocher and Beacon Island, which are situated seaward of the main group (Salm, 1977).

**Reef Structure and Corals** The reefs of the Cerf group are about 2 km across and encompass four of the islands. They have a solid and distinct edge with spurs and grooves on the eastern sides, and a more gradual transition to deeper water on the more sheltered north-western sides. Some reefs are pure *Acropora* stands (IUCN/UNEP, 1984). St Anne has fringing reef around its entire perimeter. Reefs in the area have been described by Braithwaite (1971), Rosen (1971) and Taylor (1968).

**Noteworthy Fauna and Flora** Vegetation of the islands is described briefly in IUCN (1987). A number of waders are common. The area is one of the two main breeding sites in the Seychelles for Hawksbill Turtles *Eretmochelys imbricata* (the other is at Cousin Island). Some of the best marine life is found off the north side of Moyenne where 150 species of fish have been identified.

**Scientific Importance and Research** The Fisheries Division is monitoring the fish catches of licensed fishermen. A tagging programme for Hawksbills has been in progress since 1981. Accommodation and wet laboratory facilities used to be available but have now been appropriated by the government for the National Youth Service School (IUCN/UNEP, 1984).

**Economic Value and Social Benefits** The Park is close to Victoria, a heavily built-up area, and is a popular picnic site with locals. The reefs are a major attraction and there are several glass-bottom boat operators. In some areas of the Park, residents are licensed to fish with traditional methods for their own consumption. From 1977 to 1982, 20 Mahé fishermen were also licensed to fish with two basket traps each from July to September, but this has been stopped due to abuse of the system (IUCN/UNEP, 1984).

**Disturbance or Deficiencies** Several reefs are dead from unknown causes but in the 1970s there were still some good patch reefs north of Ile aux Cerfs. *Acanthaster planci* is present and is being monitored but is not reported to have caused any major damage. Construction of the international airport and dredging in Port Victoria Harbour has caused severe siltation and coral mortality in some areas (IUCN/UNEP, 1984; Salm, 1977). Construction of a fisheries harbour and the proposed east coast road will increase the silt load. There has been some anchor damage and shells have been overcollected in the past (Salm, 1978). There has been persistent poaching of turtles by people from the Les Mamelles area on Mahé (IUCN/UNEP, 1984).

**Legal Protection** Designated a Marine National Park under the National Parks and Nature Conservancy (Ste Anne Marine) Designation Order, S.I. 21, 1973. Protective regulations are given in the St Anne Marine National Park Regulations 1973, enforced since the St Anne Marine National Park (Commencement) Notice, S.I. 47 of 19 March 1975. Water-skiing and the collection of any marine organism within the park boundaries is prohibited. Fishing is restricted to a few fishermen using traditional methods; each family is entitled to a basket trap and handline permit which must be renewed each year (IUCN, 1987; IUCN/UNEP, 1984; Salm, 1978), although it was originally recommended that there should be no fishing (Government of Seychelles, 1971).

**Management** Seven areas of shallow water reef were to be set aside as viewing areas only, and fishing and anchoring were to be prohibited but it has proved difficult to demarcate these sites. Two of these are on the north-west and south-east coasts of St Anne respectively, the other five are on the north-west sides of the other islands. Areas are demarcated for swimmers. Due to the strong south-east monsoon the park boundary buoys have to be renewed each year. There are four park rangers and a number of other staff. A police launch assists in patrolling the Park. The Park is administered by the Conservation officer at the Ministry of National Development (IUCN, 1987; IUCN/UNEP, 1984).

**Recommendations** If the east coast road scheme is carried out the effects of inevitable siltation in the Park should be monitored (IUCN/UNEP, 1984). Salm (1978) mentions long-term plans for the establishment of an oceanarium, possibly linked to a research centre, to be based at St Anne.

# SINGAPORE

## INTRODUCTION

### General Description

Singapore is situated at the southern end of Peninsular Malaysia and is surrounded by shallow, fairly turbid water. It has a total land area of 620 sq. km and comprises the main island and some 50 small islands located mainly to the south-west. Climatic and hydrographic conditions are similar to those described for Malaysia. Sea surface temperatures around the southern islands range from 27.5 to 30.8°C throughout the year with no significant differences between surface and bottom temperatures. Tides are semi-diurnal and daytime spring tides usually occur in the early morning or late afternoon, so that exposed corals escape the hot sun. Weather conditions are fairly constant throughout the year and the monsoons are mild (Chou, 1986a).

Coral reefs occur mainly around the islands south of Singapore, including Pulau Hantu, Pulau Sudong, Pulau Salu, Pulau Samakau, Sudong, Pawai, Senang, St John's and Raffles Lighthouse (Chuang, 1977; Sien and Kahn, 1987), although a small reef (Pulau Sekudu) occurs just north of the eastern tip of the mainland (Chou, 1986a). Reefs at Pulau Salu are described in a separate account. Reefs off Pulau Hantu, 10 km south of the mainland, including a patch reef off the west coast of the island, are described by Chou (1986b), Chou and Koh (1986) and Chou and Lim (1986). Despite the extensive reclamation activity which has taken place, these reefs are considered to have quite high coral cover, although coral diversity is low. On the mainland, small coral colonies are found scattered throughout the intertidal flat at Labrador Park Beach but do not form reefs. Coral genera include *Montipora, Porites, Favites, Goniastrea, Platygyra* and *Oulastrea* (Chou, 1985b). A reef off Tanjong Teritip on the south-west coast is described by Lee (1966).

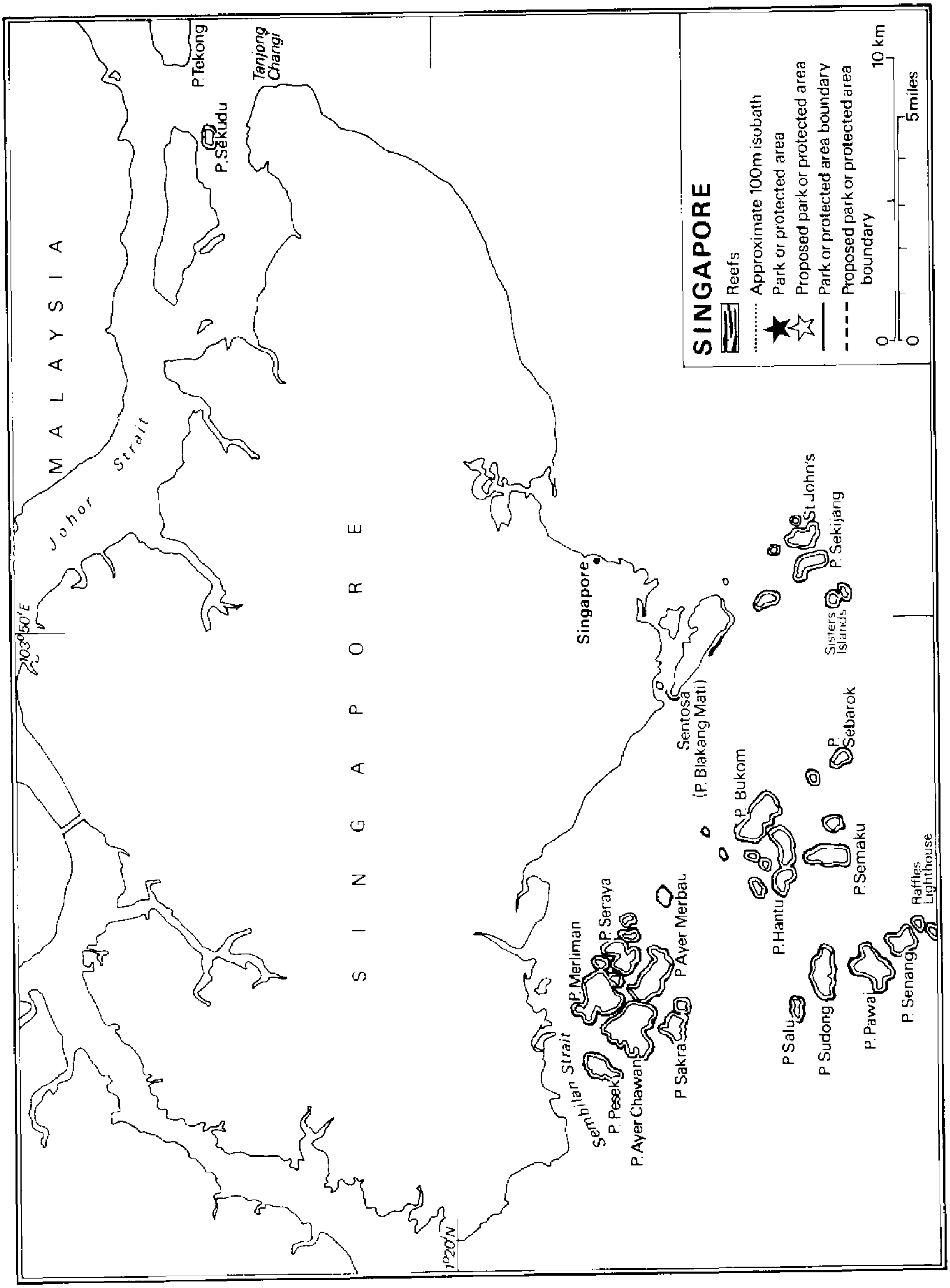
The reefs on the southern islands are mostly fringing reefs resting on either consolidated sediments or exposed igneous rock and have been classified as *Sargassum* reefs due to the predominance of brown algae (Chuang, 1977). There are a few patch reefs including Malang Papar, Batu Belalai, Pulau Damien and Cyrene (an isolated reef lying between the mainland and Pulau Bukom) which are exposed only at low tides (Chou, 1986a; Sien and Khan, 1987). The reef flat is often dominated by algae and seagrasses and has an impoverished coral community. A preliminary classification scheme based on reef flat characteristics was suggested by Chuang (1977): a) reef flat with *Sargassum* beds; b) reef flat with *Enhalus* beds; and c) open reef flat. These different reef types are described by Chou (1986a). Most reefs have a similar profile with an intertidal reef flat of variable length and a very gentle gradient. The reef edge zone is not clearly demarcated but usually occurs 5-10 m before the reef slope, where coral cover begins to increase rapidly. The subtidal reef slope is steep, almost vertical in some cases, and levels off to a sandy bottom at 16 m depth. In some areas, such as the eastern side of Pulau Jong, the slope may extend down to more than 30 m depth.

Chou (1985a), Chou and Teo (1985) and Chuang (1977) report 94 species of hard corals from Singapore reefs. Live coral cover increases progressively seawards. On the reef flat corals are generally of the massive type, predominantly the genera *Favia, Favites, Cyphastrea, Leptastrea, Goniastrea, Platygyra, Oulastrea* and *Porites* and are largely species which can tolerate periodic desiccation, changes in salinity and sedimentation. The reef edge zone is dominated by the mussid coral *Symphyllia nobilis* and the faviid coral *Diploastrea heliopora*, both of which are massive and each of which may cover up to 40%. On the reef slope, the dominant species is *Pachyseris speciosa* with a percentage cover of up to 42%. The reef slope communities are the most diverse; the most widely represented families are the Faviidae, with over 25 species, and the Fungiidae with about 12 species. Coral growth is, however, confined to the upper 12 m of the slope; below this depth, growth ceases very abruptly due to the lack of light.

Branching corals are sparse with only three species *Acropora concinna, Porites nigrescens* and *Montipora laevis* having been found at Pulau Salu. The distribution of soft corals is limited to the region between the middle reef flat and the reef edge. The most common genera are *Sarcophyton, Lobophytum* and *Sinularia* (Chou, 1986a).

About 14 species of sponge are known from the reefs, the most common being the Cork Sponge *Suberites inconstans* (Chou, 1986a). Molluscs include *Lambis lambis, Strombus urceus*, various species of *Trochus, Turbo, Nerita, Cypraea, Pyrene, Murex, Thais, Drupa* and *Conus*. Bivalves include the Giant Clams *Tridacna crocea, T. squamosa* and *Hippopus hippopus* and other genera such as *Lithophaga, Pedum, Lima, Chlamys, Cardita, Malleus, Pteria* and *Septifer*. *Sabellastarte* sp. is the only fan worm known to occur on these reefs (Chou, 1985a). Chou (1986) describes sea anemones, hydroids, echinoderms (notably the Black Sea Urchin *Diadema setosum*), crustaceans and other fauna. Macroalgae are abundant but are confined mainly to the reef flats. Brown algae include *Sargassum, Padina commersonii, Turbinaria ornata* and *Cystoseira prolifera*; green algae are represented by *Enteromorpha* spp., *Ulva reticulata, Halimeda tuna, H. opuntia* and *Avrainvillea erecta* while red algae include species of *Eucheuma* and *Gracillaria*. Other algae are described by Chou (1986a).

Most work on the reefs has been carried out at Pulau Salu (*see separate account*). Ecological studies of the reefs at Pulau Hantu are currently being undertaken by the National University of Singapore, including a comparative study of the reef slope and an artificial substrate (a concrete pillar in the adjacent jetty) (Chou, 1986b; Chou and Lim, 1986). The fringing reefs of Pulau Semakau and the Jong and Cyrene patch reef are being investigated as part of the Asean-Australian Co-operative Programme on Marine Sciences (Project on Living Coastal Resources). Projects planned for completion by 1987 include systematic and distribution studies of reef echinoderms and associated species and of selected species of stony corals and their associated species


SINGAPORE
Reefs
Approximate 100m isobath
Park or protected area
Proposed park or protected area
Park or protected area boundary
Proposed park or protected area boundary
0
10 km
0
5 miles
MALAYSIA
SINGAPORE
Johor Strait
P.Tekong
Tanjong Changi
P.Sekudu
103°50'E
1°20'N
Singapore
Sentosa (P. Blakang Mati)
St John's
P. Sekijang
Sisters Islands
P. Sebarok
P. Bukom
P.Semaku
P.Hantu
Raffles Lighthouse
P. Senang
P. Pawai
P. Sudong
P.Salu
P. Sakra
P. Ayer Merbau
P. Seraya
P. Merliman
P. Pesek
P. Ayer Chawan
Sembilan Strait

(Chou *in litt.*, 5.11.86). Other studies are largely descriptive and include Chou and Teo (1983), Chuang (1973), Goh (1963), Moll (1977), Poon (1963), Purchon (1956), Tan (1970), Williams (1976) and Yeo (1976). The reefs of Singapore serve as important models of reefs coping with a heavy sedimentaion load (Chou *in litt.*, 12.12.85). Survey methods used in reef projects to date are described in (Chou, 1984b).

**Reef Resources**

The reefs are not important for fisheries (Chou *in litt.*, 12.12.85) although there is a small amount of subsistence fishing and some sport fishing. The southern islands were once largely uninhabited apart from small fishing villages. Pulau Semakau was inhabited until the 1970s but is now uninhabited; it is visted occasionally by fishermen but the reefs are not heavily exploited (Sien and Kahn, 1987). Tourism is of increasing importance in Singapore and reef-related recreational activities are being promoted in the southern islands (Glauberman, 1985). Numerous resorts have been built, the major ones being on Pulau Hantu (reclaimed in 1974), Sentosa, Kusu, St John's and Sister's Islands (Subar Laut and Subar Darat), and others are being planned (Cheng, 1985; Sien and Kahn, 1987). Sien and Kahn (1987) provide additional information on the development of the southern islands.

**Disturbances and Deficiencies**

The reefs appear to have suffered little natural damage since the monsoons are mild and there are no records of *Acanthaster* outbreaks (Chou, 1986a). Since the 1960s, the coastal zone has undergone a dramatic transformation. Urban and industrial development and the accompanying pollution, sedimentation and physical damage are the main threats to the reefs. Prior to the land reclamation programme in the late 1960s (Cheng, 1985; Chou and Lim, 1986; Chuang, 1977; Gamboa, 1983; Lloyd and Hoe, 1985), many good fringing reefs could be found along the mainland coast especially in the south-eastern, western and south-western sectors. These have now been totally obliterated with the exception of a very short stretch at Labrador Beach. Land reclamation has had a major impact in the southern islands as well. Reef flats at Pulau Sudong, Pulau Hantu and Kusu Island have been reclaimed up to approximately 10 m before the reef slope (Chou, 1986a; Chou and Lim, 1986). In most cases, reclamation has been carried out for recreational purposes, although in the Ayer Chawan group a petrochemical complex has been constructed. A direct effect of these reclamation schemes is increased turbidity of the water which drastically reduces light penetration and thus live coral cover and coral settlement (Chan 1979; Chou, 1986a; Chou and Lim, 1986). Visibility now ranges from 1.3 m to 4.7 m even on sunny days (Chou, 1986a; Gamboa, 1984). It is expected that by 1991, when the reclamation scheme is completed, Singapore will be one-tenth bigger (Gamboa, 1983). However, land reclamation projects are slowing down and it is thought that the reefs may be adapting to the changes and showing signs of recovery (Chou *in litt.*, 12.12.85). In the 1970s, Pulau Biola was reported to have one of the few intact reefs (Chia, 1978).

Over the last decade, ornamental shells such as cowries and cones have dwindled in numbers due to excessive collecting. The Noble Volute *Voluta nobilis*, which was extremely common, is now rarely seen (Chou, 1985a and 1986a). Coral is collected for export; over 35 tonnes were exported to Hong Kong in 1982 (Foreign Trade Statistics) and from 1983-1985 about 900 tonnes of corals and shells were exported. Removal of coral by holiday makers for commercial purposes is also a serious threat. Anchor damage to the reefs has been reported (Chou, quoted by Glauberman, 1985). The port of Singapore is the world's second busiest port and there is a continuous threat of oil spills, effluent discharge and other forms of pollution (Gamboa, 1984). Coral off Labrador Beach has reportedly been killed by increased oil discharge (Sharma, 1961).

**Legislation and Management**

The authorities and agencies with jurisdiction over the coast are described in Chia (1984). In the early 1980s, the Environment Ministry began monitoring sea water quality and the marine environment is reportedly cleaner now although still turbid (Gamboa, 1984). A Coastal Resources Management Project has recently been undertaken by the Science Council, the National University of Singapore and the Primary Production Department (Anon., 1987b). Several of the southern islands, including St John's, are managed by the Sentosa Development Corporation (SDC), which has an aquarium on Sentosa Island and is currently preparing an exhibition on marine conservation.

There are no protected areas for reefs in Singapore as the Nature Reserves Act does not cover aquatic areas. A number of reefs such as Pulau Salu (*see separate account*), Pulau Sudong, Pulau Pawai, Pulau Biola and Pulau Senang are, however, within a military restricted zone, which affords some protection. Some of the best reefs are found within this zone (Chou *in litt.*, 12.12.85). On the mainland, the East Coast Park and West Coast Park are coastal areas which have been developed for recreational use, but Park designation does not include protection of the reefs. Labrador Park Nature Reserve is adjacent to the only stretch of natural rocky shore on the mainland which has reef-associated organisms, but protection does not extend to the marine environment (Chou, 1985b). The area is threatened by oil tanker unloading facilities, reclamation and effluents from the Pasir Panjang power station. The Pasir Ris mangrove on the northern coast is recommended for reserve status (IUCN, in prep.).

**Recommendations**

A reef conservation project has recently been initiated by the Republic of Singapore Yacht Club (RSYC), the Department of Zoology, National University of Singapore and the Singapore Underwater Federation. The first stage of survey work is planned for completion by 1988, following which it is hoped that one or more reefs will be protected for recreational purposes and research (Anon., 1987a). Representations are to be made to the Nature Reserve Board to emphasize the need for legislation to control reef damage and exploitation (Chou *in litt.*, 12.12.85).

SDC officials have considered putting up signboards on St John's asking people not to collect corals but there is no legal framework through which enforcement could be carried out (Glauberman, 1985). The long-term effects of the land reclamation schemes of the reefs should be carefully monitored. The construction of artificial reefs in areas where natural reefs have been damaged could promote and improve coral diversity and growth (Chou and Lim, 1986).

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**PULAU SALU**

**Geographical Location** 12 km south of the Singapore mainland, and just north of Pulau Sudong; 1°13'N, 103°15'E.

**Land Tenure** Government-owned

**Physical Features** Pulau Salu is a small isolated island with a luxuriant vegetation covering the slopes and hilltops (Chou, 1984a). The south-western side is rocky.

**Reef Structure and Corals** A fringing reef comprising a thin, superficial layer of coral on various substrates, completely surrounds the island (Chou and Wong, 1985). Like other reefs in Singapore, it has a very gentle sloping reef flat extending from the shoreline to the reef edge which culminates in a short steep reef slope ending at a depth of approximately 16 m (Chou, 1986a). Three distinct zones have been recognized:- a reef flat, reef edge and reef slope (Chou and Wong, 1985). The reef flat, which is more extensive on the northern and eastern sides of the island, is exposed during low tides and coral growth is restricted to a few hardy genera such as *Porites, Favia, Favites* and *Goniastrea* (Chou, 1984a; Chou and Wong, 1985). Soft corals are abundant on the reef flat and towards the reef edge and include *Sarcophyton, Sinnularia* and *Lobularia*. Soft corals, gorgonians, sea pens and sea whips are also present on the flat sea bed at the bottom of the reef slope. Live coral cover on the reef flat is low (maximum 2.5%) compared with that of about 75% on the reef slope (Chou, 1984a). Below 8 m, coral growth is restricted by poor light penetration.

Chou and Teo (1985) reported 42 species of scleractinian corals. The most common corals are *Fungia* spp., *Diploastrea heliopora* and *Symphyllia nobilis* (Chou, 1984a). These last two species dominate the reef edge (Chou and Teo, 1985). *Porites lutea* and *Favia speciosa* are the most abundant on the reef flat (Chou and Teo, 1985). The reef slope is dominated by *Pachyseris speciosa* (Chou, 1984a; Chou and Teo, 1985). Branching corals are extremely rare (Chou and Teo, 1985). Additional information is given in Teo (1981).

**Noteworthy Fauna and Flora** Distribution patterns of reef-associated organisms (sponges, hydrozoans, anthozoans, annelids, molluscs, platyhelminths, crustaceans and echinoderms) are described by Chou and Wong (1985). Chou (1984a) provides a popular account of reef-associated invertebrates. Of the sponges on the reef flat, the most common is *Suberites* sp.; the genera *Ircinia, Dysidea* and *Petrosia* are also present, although the latter is very rare. Red-spotted yellow sea-fans, tube worms *Sabellastarte* spp., echinoderms *Diadema setosum*, brittle stars *Ophiarachnella* spp., sea lilies *Stephanometra* spp., cushion stars *Culcita* spp. and sea cucumbers *Holothuria* spp. and *Ophedosoma* spp. are also found. Molluscs include species of *Lambis, Strombus, Turbo, Trochus, Pinna, Malleus* and *Lima*. Three species of Giant Clam (*Tridacna crocea, T. squamosa* and *Hippopus hippopus*) are present (Chou, 1984a). Fish are abundant and diverse and include butterflyfish, sea anglers, wrasses, parrotfish and damsels, and are described by Tay (1978). Chou and Wong (1984) describe the distribution of marine macroalgae. The reef is heavily dominated by *Sargassum* spp., the growth of which is seasonal, with maximum cover between October and January (Chuang, 1977).

**Scientific Importance and Research** Pulau Salu is the best-studied of the reefs of Singapore, and a number of publications have appeared as a result of a project to investigate the ecology of the reef, carried out by the National University of Singapore with the support of the Singapore Institute of Biology (Chou and Teo, 1985; Chou and Wong, 1984; Chou and Wong, 1985). The reef provides a model of an equatorial sediment-stressed *Sargassum* reef (Chou and Wong, 1985). It is considered one of the richest reefs in Singapore (Chuang, 1961).

**Economic Value and Social Benefits** Snorkelling, SCUBA diving and sportfishing are popular activities. The island is uninhabited (Chou and Teo, 1985).

**Disturbance or Deficiencies** The high sedimentation load of the surrounding water affects coral growth rates. Land reclamation schemes at nearby Pulau Sudong over the last two decades have caused water turbidity and siltation on the reef flat to increase but the reef slope appears unaffected (Chou, 1984a; Chou and Wong, 1985). Some mollusc species such as *Lambis, Strombus* and *Turbo* appear to have declined in numbers over the years and cones, cowries and volutes are now rarely seen. Only small individuals of Giant Clams are now found, large individuals having apparently been collected (Chou, 1984a).

**Legal Protection** None specifically for the reef area, although its inclusion in the restricted zone of the Ministry of Defence currently provides protection.

**Management** None known.

**Recommendations** Given the scientific interest of the reefs of Pulau Salu, and the long term studies which have been carried out here, consideration might be given to creating a scientific reserve in the area.

# SOMALIA

## INTRODUCTION

### General Description

Somalia has the longest coastline of the tropical East African countries, with 2000 km facing the Indian Ocean and 1300 km facing the Gulf of Aden. The most northern point is Ras Asir (Cape Guardafui) at about 12°N, and from here the coast extends south to the border with Kenya at about 2°S. Most of the coastline consists of a series of sandy beaches and bays interrupted in places by rocky cliffs and headlands (Salah, 1983). The climate is arid, with 75% of the country receiving less than 300 mm rain a year, the south receiving a little more than the very dry north. Two major rivers which are mainly fed from highlands west of Somalia pass through the south: the Shabelle (Shebelle) and the Jubba which it joins in the far south to enter the Indian Ocean at Kismaayo (Chisimaio, Kismayu) (Stromme, in prep.).

The principal coastal currents follow the direction of the winds. During the south-west monsoon (April-October) the East African Coastal Current flows north along the coast and near Socotra merges with the South-west Monsoon Current which flows north-east from the Gulf of Aden. From November to March, the north-east monsoon generates a southward-flowing current along the Somali coast called the Somali Current which meets the East African Coastal Current near the Kenya-Somali border. In the Gulf of Aden a south-west flowing current is generated called the North-east Monsoon Current. During the south-west monsoon, upwellings of cold, highly productive water are experienced along the eastern Somali coast, between Raas Macbar (Ras Mabber) and Raas Xaafuun (Ras Hafun) and off Raas Caseyr (Ras Asir). This causes nutrient enrichment of these waters to the benefit of the small fisheries industry. Surface water temperatures may exceed 30°C in the south and in lagoons (Couper, 1983; Elder, in prep.).

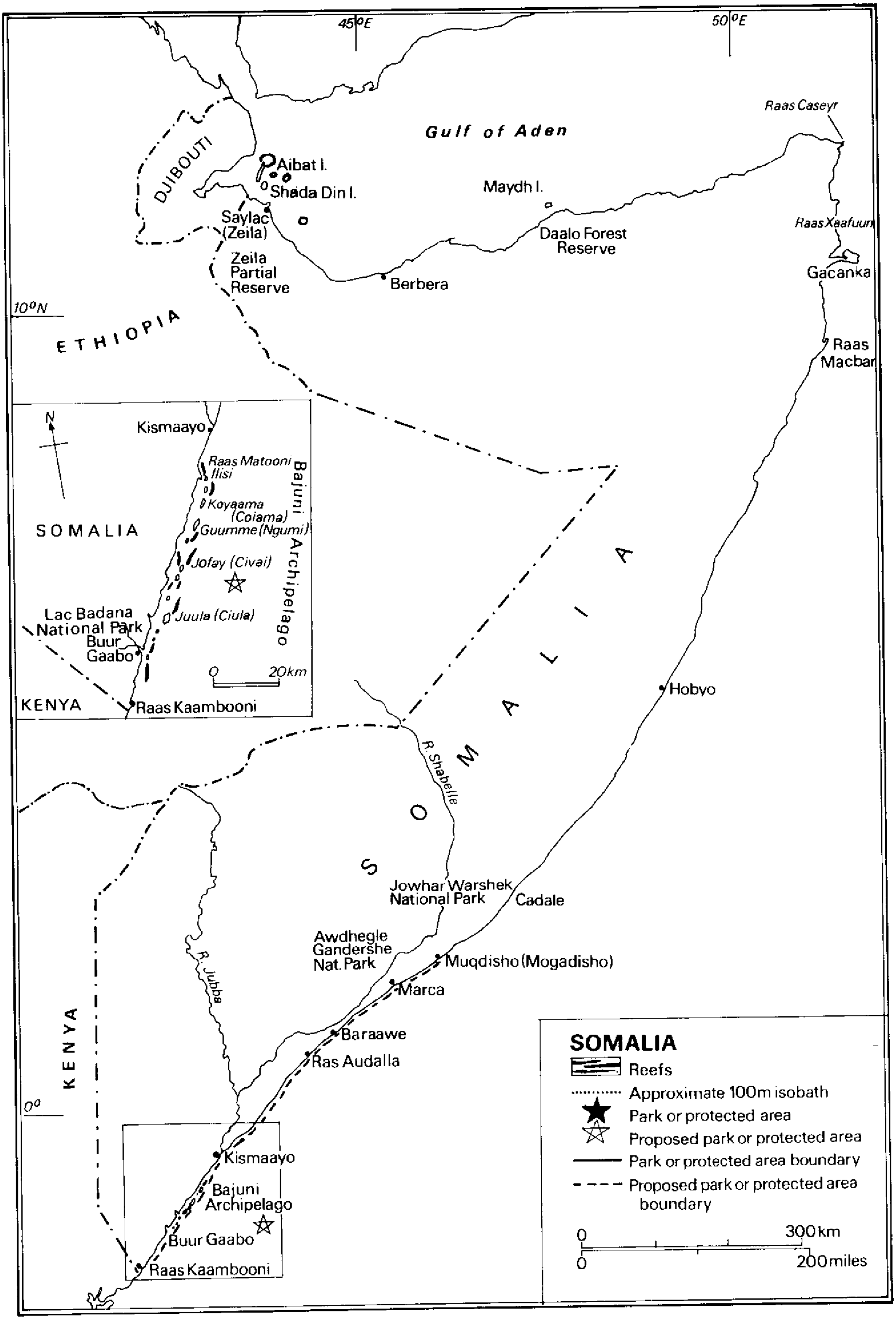
There are no reefs along the coast facing the Gulf of Aden due to upwellings and seasonal cold water currents (Stromme, in prep.). On the east coast, the continental shelf is widest between Raas Caseyr and Raas Macbar, extending up to 60 km from shore, and the coast is dominated by rocky cliffs with no or very narrow beaches. Further south the continental shelf narrows, to 15-30 km near Cadale (Adale) and only 6 km between Muqdisho (Mogadishu) and Ras Audalla. The shoreline slopes more gently seawards here and ends in sandy beaches (Salah, 1983). Seasonal cool water upwellings inhibit coral growth along much of the northern part of this coast (Hamilton and Brakel, 1984). However, Darwin (1842) mentioned a coral reef, extending for four or five miles (6.4-8 km), at 10°1'N, which corresponds with the cold upwelling region; it is described as a fringing reef lying a quarter of a mile (0.4 km) off shore with a lagoon of 6-10 feet (1.8-3 m) depth.

South of Cadale to the Kenyan border, the continental shelf continues to be fairly narrow and reefs form an interrupted barrier about 100-1000 m from the shore and up to 7 km from the shore near Kismaayo (Elder, in prep.; Singh, 1983). This consists of living coral superimposed on fossil reef, the only major break being off Muqdisho. In this area, corals are limited to sparse patches among major seagrass beds, some small patch reefs, and fairly rich coral communities, although of low diversity, on the seaward slopes (Carbone and Matteucci, 1984). From 20 km south of Marca (Merca) to Kismaayo, the reef is noticeably less than 500 m off shore and in several places converges with the shoreline.

South of the equator, the Bajuni Archipelago lies about 1 km off shore, parallelling the coast for about 100 km from Kismaayo south to the Kenyan border. It forms a long barrier within which the water is generally shallow and relatively calm (Matteuci, 1984) with a reef flat typical of those found in shore of the reefs further south in Kenya and Tanzania. North of Kismaayo, similar islands occur only near Marca and Baraawe (Brava) (Elder, in prep.). The coastal carbonitic sedimentation is being studied in this area and a coral species list is being compiled (Mateucci *in litt.*, 7.12.84). The sediments are primarily carbonate skeletal fragments and support extensive seagrass beds. Where water movement is greater, occasional patch reefs flourish, and to seaward of the islands there are fringing reefs. Angelucci *et al.* (1982) describe the reefs around Ilisi Island, which lies in the centre of the chain. The lagoon between the mainland and the island is about 3 m deep and is densely colonized by *Thalassodendron*, with corals limited to occasional patches. To seaward there is a reef flat nearly 1 km broad, covered largely with coarse sand and gravel derived from corals; live corals are sparse. The reef edge leads to a steep slope and both are dominated by branching *Porites* species and the latter also by the soft coral *Sarcophyton*. The reef slope descends to an extensive sandy plain at 6-8 m depth. A popular description of the reefs, turtles and other marine resources of the Bajuni Archipelago is given in Travis (1967).

In the far south, the Bay of Buur Gaabo (Bur Gavo, Burkavo) is bordered by dense mangrove stands, with poor growths of encrusting and massive corals, and scattered milleporids in its outer reaches (Matteucci, 1984). Less is known about the coral fauna of this coast than about any of the other East African countries but it may be expected to resemble that of Kenya.

Hard substrates are dominated by macrophytic algae in the north and large seagrass beds occur along the southern coast (Elder, in prep.). These undoubtedly provide food for Dugong *Dugong dugon* and turtles (Salah, 1983; Elder, in prep.). Dugong are thought to be present in the mangrove areas between Kismaayo and Raas Kaambooni (Chiamboni). Although poorly documented, large numbers of Green Turtles *Chelonia mydas* and Hawksbill *Eretmochelys imbricata* occur on parts of the north and east coasts but there is no information on nesting beaches (Stromme, in prep.; Elder, in prep.). The status of breeding seabirds on the Somalia coast, Maydh Island (Muit) and the islands off Saylac (Zeila) (in the Gulf of Aden) is described by Cooper *et al.* (1984). Although population numbers are largely unknown, several species of tern *Sterna* spp. and the Sooty Gull *Larus hemprichii* nest on the coastline. Maydh Island is an important Brown Noddy *Anous stolidus* rookery, and the Saylac Islands used to support a


45°E
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Gulf of Aden
Raas Caseyr
DJIBOUTI
Aibat I.
Shada Din I.
Maydh I.
Saylac
(Zeila)
Zeila
Partial
Reserve
Daalo Forest
Reserve
Raas Xaafuun
Gacanka
Berbera
10°N
ETHIOPIA
Raas
Macbar
N
Kismaayo
Raas Matooni
Ilisi
Koyaama
(Coiama)
Guumme (Ngumi)
Bajuni Archipelago
SOMALIA
Jofay (Civai)
Lac Badana
National Park
Buur
Gaabo
Juula (Ciula)
0 20km
KENYA
Raas Kaambooni
SOMALIA
Hobyo
R. Shabelle
Jowhar Warshek
National Park
Cadale
Awdhegle
Gandershe
Nat. Park
Muqdisho (Mogadisho)
Marca
R. Jubba
KENYA
Baraawe
Ras Audalla
0°
Kismaayo
Bajuni
Archipelago
Buur Gaabo
Raas Kaambooni
SOMALIA
Reefs
Approximate 100m isobath
Park or protected area
Proposed park or protected area
Park or protected area boundary
Proposed park or protected area
boundary
0 300km
0 200miles

colony of many thousands of Bridled Terns *S. anaethetus*. Stromme (in prep.) gives a brief description of fish distribution. Mangroves are found in tidal creeks along the coast of southern Somalia.

**Reef Resources**

Two per cent of the Somali population earn their living from fisheries and the coastal population is estimated at about one million. Singh (1983) and Stromme (in prep.) describe offshore commercial fishing operations. Artisanal fishing is scattered along the entire Somali coast and is reef-based south of Hobyo (Obbia) but detailed information is not available (Stromme, in prep.). The most important species caught in reef areas include sharks, lethrinids, serranids (groupers), lutjanids (snappers), pomadasyids (grunts) and sparids (seabreams). At least 50 tonnes of spiny lobster *Panulirus* spp. are caught off the south coast on the reef flat and in shallow areas outside the reef but catches are limited as there are currently no facilities for SCUBA diving in this area. The number of active lobster fishermen has declined over the last decade. Turtles are of economic importance and the catch is discussed by Simonetta (1982) and Elder (in prep.).

There is considerable potential for the development of tourism along the coast and a Ministry of Tourism has been established for this purpose. The five year development plan 1982-1986 places heavy emphasis on the improvement of tourist facilities. The Ministry has plans to develop tourism near Lac Badana National Park and the development is to include parts of the National Park, offshore islands and coral reefs. There is also a proposal to develop a resort area on one of the beach areas near Muqdisho. Diving and snorkelling are already popular in this region (Singh, 1983).

**Disturbances and Deficiencies**

Somalia is the least populated and, partly due to the unfavourable soils over much of its surface, the poorest of the East African coastal nations. Soil erosion could threaten its marine life and reefs. The Shabelle River already carries a large volume of sediment to the coast where it may smother marine habitats (Finn, 1983). Coastal bluffs south of Muqdisho have been desertified as a result of overgrazing since 1978 and 5000 sq. km of shifting dunes have been created, of which only 1% has been restabilised. A large area of the coast has been covered with shifting sand as a result (Kundaeli, 1983). Sand mining on the beaches is widespread and potentially could cause not only coastal erosion but also alteration of water circulation and increased turbidity, which would affect the reefs (Singh, 1983). Live coral is removed in the reef area off Muqdisho and other southern coastal ports to allow passage of vessels and to increase the flushing of water inside the reef to remove domestic wastes (Elder, in prep.).

Marine pollution is not a major problem at present but there are localized incidents, for example around Muqdisho where raw sewage discharge has had some impact. There is some industrial pollution. A number of countries are exploring for oil on the Somali continental shelf (Singh, 1983). Muqdisho is a major port and there is potential for pollution from ship traffic. There are no data on pollution resulting from an oil refinery near Muqdisho but oil balls are occasionally found along the beaches (although these may originate from oil tankers passing off shore) and small spills are not uncommon during loading operations. The risk of oil pollution from a variety of sources is discussed in Ross (in prep.).

There is some concern about the future of the fishery stocks although currently there are no visible problems (Stromme, in prep.; Elder, in prep.). Total fishing effort decreases during the south-west monsoon but is restricted to the limited area within the reefs where it may be intensive. There is potential for considerable overexploitation. Furthermore there are plans to increase production of spiny lobster, groupers and snappers which could cause problems. Spiny lobster production could increase from 50 to 150 tonnes a year, by the replacement of free-diving with SCUBA or by the recruitment of more fishermen. Shells, reportedly from southern Somalia, are sold in about 20 shops in Muqdisho but the impact of this exploitation is not known. According to fishermen in Marca, Baraawe and Kismaayo shells are only incidentally harvested during other fishing activities (Elder, in prep.).

**Legislation and Management**

Somalia has signed the Convention for the Protection, Management and Development of the Marine and Coastal Environment of the Eastern African Region and the Protocol concerning Protected Areas and Wild Fauna and Flora in the Eastern African Region. It has also signed the Convention on the Conservation of the Red Sea and Gulf of Aden Environment. It expects to ratify all these before the end of 1986 (Elder, in prep.).

The National Range Agency within the Ministry of Livestock, Forestry and Range is responsible for National Parks but there are no marine protected areas and no legislation concerning their establishment or management (Kundaeli, 1983; Elder, in prep.). The 1984 Tourism Act however has provisions for the protection and preservation of ecology and environment and for planning for marine protected areas. New legislation, modelled on Kenyan wildlife legislation, is being prepared which will provide for the establishment of a network of protected areas covering all aspects of Somali wildlife. A plan developed in 1977 to establish an oceanographic institute and marine science station in Muqdisho (Rifai, 1980) has not been followed up.

The Ministry of Fisheries is responsible for the development and management of fishery resources. Basic marine fisheries legislation is contained in the Maritime Code (Legislative Decree No. 1, 31.2.59) amended by Decree Law No. 7 of 1.11.66. Law No. 3 of 7.1.67 entrusts fisheries legislation to the maritime authority which now falls under the Ministry of Marine Transport and Ports. Fishing is only allowed by concession from the Ministry of Fisheries. Article 70 of the maritime code allows the prohibition of fishing in certain areas and Article 71 prohibits dynamite, electric current, chemical or similar fishing methods (Singh, 1983). Somali Marine Products controls much of the fishing industry. Since the 1970s, the government has encouraged and supported the development of fishing co-operatives and there are a number of development projects which aim to increase the efficiency of local fishing effort (Stromme, in prep.; Elder, in prep.). Somali Marine Products has set a minimum size-limit of 23 cm and 460 gm on the lobsters it will purchase but undersize specimens may be sold elsewhere. There are no legal regulations governing the lobster harvest (Elder, in prep.).

At present there is no legislation to control pollution through the discharge of oil from ships, but in 1983 new legislation was in preparation which would cover this (Singh, 1983). Existing pollution legislation concerns only ships in ports and Somalia is not yet party to any international conventions relating to marine pollution.

## Recommendations

Elder (in prep.) gives recommendations for the development of an action strategy for marine conservation in Somalia. International conventions relevant to marine conservation should be ratified. A formal mechanism to establish, manage and administer marine and coastal protected areas should be developed. Appropriate legislation should be drafted. The Ministries of Livestock, Forestry and Range, of Fisheries and of Tourism should be involved in the formulation and implementation of this mechanism. In the short term, the National Range Agency should take the initiative.

The distribution of critical marine habitats and species should be surveyed. Priority should be given to the fringing reef area between Cadale and Kaambooni, particularly the coral island-reef-mangrove system between Kismaayo and Kaambooni, including the Bajuni Archipelago, since this is most affected by development activity and coastal resource exploitation. Subsequently the north coast from Djibouti to Raas Xaafuun and the area from Raas Xaafuun to Cadale should be surveyed. Fourteen terrestrial areas have been designated for protection (Simonetta and Simonetta, 1983), of which six are bordered by or are adjacent to the coastline, including Awdhegle-Gandershe, Daalo Forest Reserve, Jowhar Warshek, Lac Badana (Bush Bush National Park) and Zeila (Saylac). These could provide administrative infrastructures for marine reserves. For example, Lac Badana National Park could be extended to include the Bajuni Archipelago, with a single management plan and administered by one authority. Turtle reserves have been proposed in the draft of new legislation.

Surveys of the proposed tourism developments near Muqdisho and Lac Badana National Park should be carried out immediately with the aim of proposing marine protected areas at these sites.

A coastal zone plan falls within the 1982-1986 five year development plan. Ross (in prep.) makes recommendations for oil spill contingency plans and improved oil pollution control. A regular effort should also be made to monitor the taking of marine turtle, ornamental shells and lobsters. The lobster fishery should be studied to determine its sustainability and surveys of turtles, dugong and marine molluscs should be undertaken (Elder, in prep.). Stromme (in prep.) recommends that the reef fisheries are monitored by Somali Marine Products. A national programme for training personnel in marine conservation should be formulated.

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# SOUTH AFRICA

## INTRODUCTION

### General Description

Although the southernmost coral reefs of the western Indian Ocean are at Inhaca Island, just north of the South African border, coral communities are found in South Africa. These are located off the Maputaland (Tongaland) coast and extend south to Leven Point (Grindley *et al.*, 1976). The dominant current throughout the year is the Agulhas Current which flows southwards from Mozambique and rarely falls below 21°C. The mean sea water temperature for Maputaland is 26.5°C (van der Elst, 1982). In January (the austral summer), winds come from the north-east, while in July (the austral winter) winds prevail from the south-west. The tides in the region where corals occur are semi-diurnal, with a range of 2-4 m (Couper, 1983). Additional information on the hydrology and climate of the South African coastline is given in Tinley (1985).

The Maputaland area is the only really subtropical part of the South African coastline. Conditions favour the growth of corals, reef fish and a variety of Indo-Pacific fauna and flora, but true reef formation does not occur to a marked degree. Although virtually indistinguishable from true reefs, the coral communities consist of an encrustment of sandstone reefs. These are composed of a sandy calcarenite which represents lithified cores of former coastal sand dunes formed during and after the Saalian glaciation, 130 000 to 140 000 years ago. They are abundantly colonized by corals and other groups of benthic and pelagic biota normally associated with true coral reefs (Boshoff, 1979, 1980 and 1981; Heydorn, 1972 and 1982). The area is an important transition zone between true reef areas and areas where luxuriant reef communities occur on non-limestone substrates. Coral communities in the St Lucia Marine Reserve are described in the following account. Further south, the marine benthos is dominated by macrophytic red and green algae but several species of coral are found in sheltered, intertidal pools on rocky parts of the coast, as far south as Port Elizabeth and Cape Town. There is also considerable coral in deep water off this area (Crossland, 1948; Bourquin *in litt.*, 29.12.86). These include species in the genera *Stylophora, Pocillopora* and *Balanophyllia*. Research on the coral communities of South Africa is currently underway at the Oceanographic Research Institute in Durban which, through the University of Natal, was surveying the reefs from the Mozambique border to Lake St Lucia, including the Kosi Bay and St Lucia Marine Reserve region, in the early 1980s (Heydorn, 1982).

Marine algae of Maputaland are described by Seagrief (1980). More than 80% of all marine fish known for South Africa are found along the Maputaland coast, at least 1200 species having been recorded including tropical, temperate (European), endemic and circumglobal species (van der Elst, 1982). Marine molluscs are described by Kilburn and Rippey (1982) and the distribution of palinurid lobsters on the Maputaland coast has been described by Berry (1971 and 1974). The Leatherback *Dermochelys coriacea* and the Loggerhead *Caretta caretta* Turtles nest in significant numbers. The Olive Ridley *Lepidochelys olivacea* nests rarely and Green *Chelonia mydas* and Hawksbill *Eretmochelys imbricata* Turtles are occasional visitors (Groombridge, 1982; Heydorn and Hughes, 1969; Hughes, 1974 a and b; Kwazulu Conservation Trust, 1977; Werger, 1978). Croxall *et al.* (1984) list the seabird species breeding in South Africa.

Mangroves are plentiful from Mtuzini northwards and also occur sporadically along the east coast to as far south as the mouth of the Gonabie (Gonubie) (32°55'S). Their southward distribution on the west coast is limited by the cold upwelling waters of the Benguela Current. Relatively undisturbed communities are found at Mngazana (Umngazana), 31°40'S, on the east coast (Werger, 1978), and the Kosi Bay mangrove system, adjacent to the proposed Maputaland National Park (Greig, 1982).

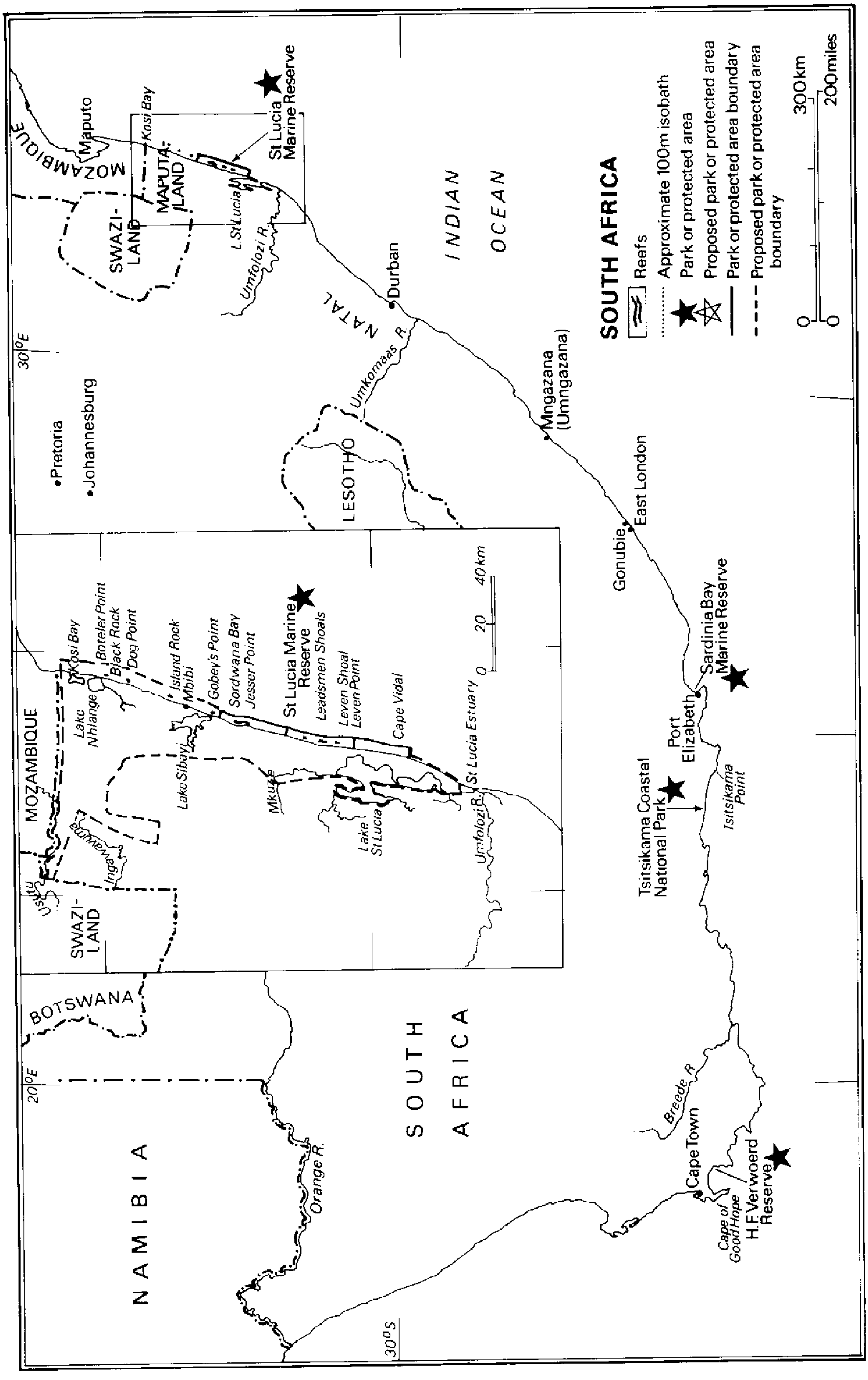
### Reef Resources

The Tonga people, who live adjacent to the St Lucia Marine Reserve, harvest moderate quantities of mussels, oysters, *Pyura*, limpets and barnacles from the intertidal zone during low spring tides. Their methods are primitive but these foods add significantly to their animal protein requirements. The east coast of South Africa is a popular area for shell collectors; cones and cowries are found in moderate abundance, as well as the popular *Charonia lampas pustulata* which is taken by divers (Werger, 1978).

There is considerable recreational fishing in the region, much of it from small craft that are launched from the beaches at Sodwana Bay and Cape Vidal. Since 1986 the capture of reef fishes has been prohibited, and catches now consist of pelagic gamefish, such as King Mackerel, Yellowfin Tuna and four billfish species. Extensive catch and effort data exist at the Oceanographic Research Institute, Durban (Bowmaker *in litt.*, 5.2.87).

### Disturbances and Deficiencies

There have been no outbreaks of *Acanthaster*, although occasional specimens are found (Heydorn, 1972). The Maputaland reefs are largely unspoiled (van der Elst, 1982), being situated well away from the main South African industrial areas and to the north of the region influenced by run-off from Natal's rivers. However, occasional heavy flooding from the Mfolosi and Tugela Rivers to the south, when coupled with the north-flowing inshore current, permits turbid water penetration, which poses a moderate threat to coral communities in the region (Bourquin *in litt.*, 29.12.86). Other potential threats include heavy visitor pressure, given the rapid growth of tourism and recreational use of the coast, although this already appears to be well under control, and the possibility of the creation of a harbour at Kosi Lakes, adjoining the lakes and turtle breeding beaches (Bowmaker *in litt.*, 5.2.87). General information on threats to marine life in South Africa is given in Robinson (1976).


SOUTH AFRICA
Reefs
Approximate 100m isobath
Park or protected area
Proposed park or protected area
Park or protected area boundary
Proposed park or protected area boundary
0 300km
0 200miles
INDIAN
OCEAN
MOZAMBIQUE
Maputo
Kosi Bay
MAPUTALAND
SWAZI-LAND
St Lucia Marine Reserve
L.St Lucia
Umfolozi R.
Durban
NATAL
Umkomaas R.
30°E
Pretoria
Johannesburg
LESOTHO
Mngazana (Umngazana)
East London
Gonubie
Sardinia Bay Marine Reserve
Port Elizabeth
Tsitsikama Coastal National Park
Tsitsikama Point
Breede R.
Cape Town
H.F.Verwoerd Reserve
Cape of Good Hope
BOTSWANA
NAMIBIA
SOUTH AFRICA
Orange R.
20°E
30°S
Boteler Point
Black Rock
Dog Point
Island Rock
Mbibi
Gobey's Point
Sordwana Bay
Jesser Point
Leadsmen Shoals
Leven Shoal
Leven Point
Cape Vidal
St Lucia Estuary
Lake Nhlange
Lake Sibayi
Mkuze
Lake St Lucia
Usutu
Ingwavuma R.
0 20 40 km

**Legislation and Management**

Collection of live corals is minimal and restricted to research projects. Collection of live molluscs by hobbyists is controlled by the Natal Parks Board through the issue of permits (Vincent *in litt.*, 11.2.85). Detailed proposals for Marine Reserves were drawn up by Grindley *et al.* (1976) and a number of these suggestions have been acted upon. Corals have been recorded from the following reserves: the St Lucia Marine Reserve on the Maputaland coast (*see separate account*); Sardinia Bay Marine Reserve, near Port Elizabeth (Brynard *in litt.*, 13.4.82), which has a predominantly rocky shore (McLachlan, n.d.); Tsitsikama Coastal National Park, west of Port Elizabeth (Tietz and Robinson, 1974) and H.F. Verwoerd Reserve near Cape Town (Brynard *in litt.*, 13.4.82).

**Recommendations**

All the Maputaland coral reefs now fall within proclaimed marine reserves and consequently all the biota are protected or managed (Bourquin *in litt.*, 29.12.86).

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## ST LUCIA MARINE RESERVE

**Geographical Location** on the Natal coast, Maputaland, stretching from 1 km south of Cape Vidal to 11 km north of the Mgoboseleni Stream at Sodwana Bay; 32°33'E, 28°08'S; 32°42'E, 27°26'S.

**Area, Depth, Altitude** St Lucia Marine Reserve consists of two contiguous areas, covering a length of 79 km of coast and an area of 23 700 ha, and stretching from low water to 5.6 km out to sea. Within the St Lucia Marine Reserve No. 1, is a sanctuary area, St Lucia Marine Reserve No. 2, which stretches for 25 km from Leven Point to Red Cliffs.

**Land Tenure** Ownership of the sea rests with the State President, under the Seashore Act No. 21 of 1935; the adjacent land is also state-owned.

**Physical Features** The adjacent coastal plain consists of sand, alluvial soils and terrace deposits along the margins of the adjacent St Lucia Lake. The littoral waters of Maputaland are generally clear with visibility up to 50 m (Berry, 1980). Prevailing winds are mainly north-easterly and south-westerly. Freshwater input is limited to seasonal rain and the discharge of the Mgobezeleni River. Periodically, however, sediment-laden water is discharged during storms and cyclones. The climate and other physical features are described in Anon. (1985).

Reefs or thriving coral communities on sandstone outcrops, are found off Sodwana, Jesser Point, and at a further four localities between Jesse Point and Leven Point, north of Lake St Lucia, and lie 1-2 km offshore (Bruton and Cooper, 1980). The most extensive community is on Leadman Shoals, north of Leven Point (Berry, 1980).

**Reef Structure and Corals** Sixteen coral species are listed for the St Lucia Marine Reserve, principally some pocilloporids and faviids and one *Acropora* species, *A. africana*. Four species are ahermatypic (Brynard *in litt.*, 13.4.82) and several species occur in sheltered, intertidal pools on the coast as well as on the offshore platforms.

**Noteworthy Fauna and Flora** Five species of turtles occur within the Reserve but nesting has not been reported. It is planned to translocate eggs of the Loggerhead *Caretta caretta* to a new nesting site within the reserve. The sea snake *Pelamis platurus* is found and the Nile Crocodile *Crocodilus niloticus* is seen on the beach during floods. A total of 728 species of fish were recorded from the area between Cape Vidal and Kosi Lake in the 1970s. Additional species have been recorded adjacent to the reserve area and therefore may be expected to occur within it; it is considered that the total fish fauna for the reserve may be 1200 species (Smith, 1980). Lists of birds, marine mammals, molluscs and other invertebrates and algae recorded in the reserve are given in the management plan (Anon., 1985). Invertebrates and marine algae within the reserve were described by Jackson (1976). Mangroves are found at Sodwana. Plankton blooms are described by Grindley and Heydorn (1970).

**Scientific Importance and Research** The Oceanographic Research Institute through the University of Natal was surveying the reefs from the Mozambique border to Lake St Lucia, including the Kosi Bay and St Lucia Marine Reserve region, in the early 1980s (Heydorn, 1982). It is currently carrying out reef-related research with the support of the Natal Parks Board. The National Institute for Oceanology is also working in the region (Bowmaker *in litt.*, 5.2.87). Proposals for research in the Reserve are given in Anon. (1985) and include a long-term research project on the coral communities and their associated fauna and flora.

**Economic Value and Social Benefits** Sodwana Bay, Cape Vidal, St Lucia and Jesser Point are popular recreational sites for boating, swimming, deep sea fishing and other water sports (Natal Parks Game and Fish Preservation Board, 1981). Many of the reefs are visited by SCUBA divers (Bruton and Cooper, 1980).

**Disturbance or Deficiencies** The reefs are potentially vulnerable to heavy diver pressure (Vincent *in litt.*, 1985). Better access is bringing large numbers of visitors to Sodwana Bay in the holidays, putting considerable pressure on the reefs (Heydorn, 1982).

**Legal Protection** St Lucia Marine Reserves Nos 1 and 2 were proclaimed in the government gazette No. 6309 of 23 February 1979 under the Sea Fisheries Act No. 58 of 1973, which defines the areas and lays down regulations for the control of the capture or disturbance of "fish" (the definition covers almost all marine life) therein from the low water mark seawards. Proclamation No. 35 of 1979, issued under the Natal Nature Conservation Ordinance No. 15 of 1974, applies to the seashore contiguous to the Reserve, between low and high water marks and also controls fish take. Above the high tide mark is a Coastal Forest Reserve which follows the western margin of the coastal dune forest and stretches for a variable distance inland. The Admiralty Reserve, 46 m wide, is under the Control of the Department of Community Development, and the dunes are controlled by the Directorate of Forestry and the Department of Environment Affairs (Anon., 1985).

The St Lucia System was designated a Wetland of International Importance on 2.10.86. The St Lucia Marine Reserve is adjacent to Sodwana Bay State Forest (established in 1956 for the protection of mangroves and forest dunes, and a popular game fishing, camping and resort area) and lies close to the St Lucia Park (a 1 km strip of land around the estuary) and St Lucia Game Reserve (which includes the lake). These areas are described in Greyling and Huntley (1984) and IUCN (1987).

Fishing of any species other than pelagic teleosts and elasmobranchs is prohibited within St Lucia Marine Reserve No. 1, and all fishing is prohibited in the sanctuary area, St Lucia Marine Reserve No. 2. Within the latter, no activity is permitted and vehicle access is restricted to transit traffic only. Elsewhere in the reserve, bathing, picnicking, rod and line angling and spear and ski-boat fishing for game fish are permitted. No bait may be collected but supplies are available to anglers at Sodwana Bay and Cape Vidal.

**Management** The Natal Parks Board manages the area (Anon., 1979) and past and present management regimes are described by Crass (1976) and Anon. (1985). The boundaries are marked by beacons, placed at each end of the Reserve and at each end of the Sanctuary Area. In the latter case there is also a notice indicating that people are entering or leaving the Sanctuary Area. Only suitable beach vehicles are permitted access to the beach; a system of free permits has been introduced for this purpose and also to give Board staff the opportunity to inform visitors about the Reserve and ask for their cooperation. There is generally little trouble in the management of the reserves, and good relations have been established between park authorities and the public (Natal Parks, Game and Fish Preservation Board, 1981). Grindley *et al.* (1976) point out that conservation of the area had been requested by divers and fishermen.

**Recommendations** The area concerned lies within the Maputaland National Park which is shortly to be proclaimed and is described in detail by Bruton (1980). Underwater trails are proposed at Mbibi (which lies outside the existing Reserve) and Jesser Point. A description of the proposed zoning scheme for the St Lucia Marine Reserve is given in the management plan (Anon., 1985) and includes an Intensive Use Zone, a Limited Use Zone, a Wilderness Zone (subdivided into Pristine Area and Wild Area) and a Special Zone (with the strictest protection measures). It is planned that visitor and educational facilities should be improved.

# SRI LANKA

## INTRODUCTION

### General Description

Sri Lanka lies on the same continental shelf as India and is separated from it by water mostly less than 20 m deep. It has a low-lying coastal plain with a mountainous interior. There are three main climatic zones. The large Low Country Dry Zone comprises the northern half of the island and the plains of the east coast and has one monsoon, with less than 1900 mm rain a year. The Low Country Wet Zone in the south-west receives between 1900 and 5100 mm rainfall a year from both the south-west and the north-east monsoons. The Hill Zone of the interior has a similar rainfall to the south-west (Hoffmann, 1983).

Surface currents tend to follow the monsoon winds. For several months at the end of each year currents come from the north-east, the Bay of Bengal and along the coast of India, rather than from the open ocean, which increases sedimentation in inshore waters. In general, the sedimentary regime of coastal waters is classed as terrigenous rather than calcareous (Couper, 1983) although calcareous sediment patches may dominate near coral reefs. A detailed description of the marine and coastal environment is given in UNEP (1986).

Although widely reported in popular literature, Sri Lankan corals have been relatively little studied. Early studies include Ridley (1883), Ortmann (1889) and Bourne (1905) who describe coral collections. The only major account is that of Mergner and Scheer (1974) who describe the biological structure of the reefs of Hikkaduwa. Pillai (1972) reports a total of 90 species of stony coral for Sri Lanka in 39 genera; Scheer (1984) lists 40 scleractinian coral genera. The National Aquatic Resources Agency (NARA) has set up a coral reference collection with 134 species, including 59 new to Sri Lanka (De Silva, 1986a; Rajasuriya, 1986). There are reportedly few purely coralline reefs but there are extensive areas of coral around the coast, mainly close to the shore. Most consist of corals growing on ancient sandstone (largely along the west coast) or gneiss or granite outcrops (along the east coast) (De Silva, 1986a; Jonklaas, 1984; Salm, 1975a and 1975b).

In the north, the Jaffna Peninsula has extensive areas of coral inshore, although the water is reportedly usually green or turbid (Hoffmann *in litt.*, 15.1.85; Jonklaas *in litt.*, 31.10.84). Corals are also reported to occur around Delft, Palitivu and Iranativu Islands off the north-west coast (Hoffmann *in litt.*, 15.1.85). Reefs in Palk Bay and the Gulf of Mannar are also described in the section on India. On the west coast, Vankalai, Silavatturai and Arippu are three reefs, over 5-7 miles (8-11 km) long and lying 4-5 miles (6.4-8 km) off shore in the Gulf of Mannar, with abundant coral formations although usually turbid water (Jonklaas, *in litt.*, 31.10.84; Salm, 1975a). Other reefs on this coast include Bar Reef, west of Karaitivu Island (north of Kalpitiya), also off shore and apparently still in very good condition and Kandakuliya with two extensive coral areas. Coral reefs are few in this area although they do occur around the Karaitivu Islands, and it is mainly important for seagrasses, mangroves and associated fauna.

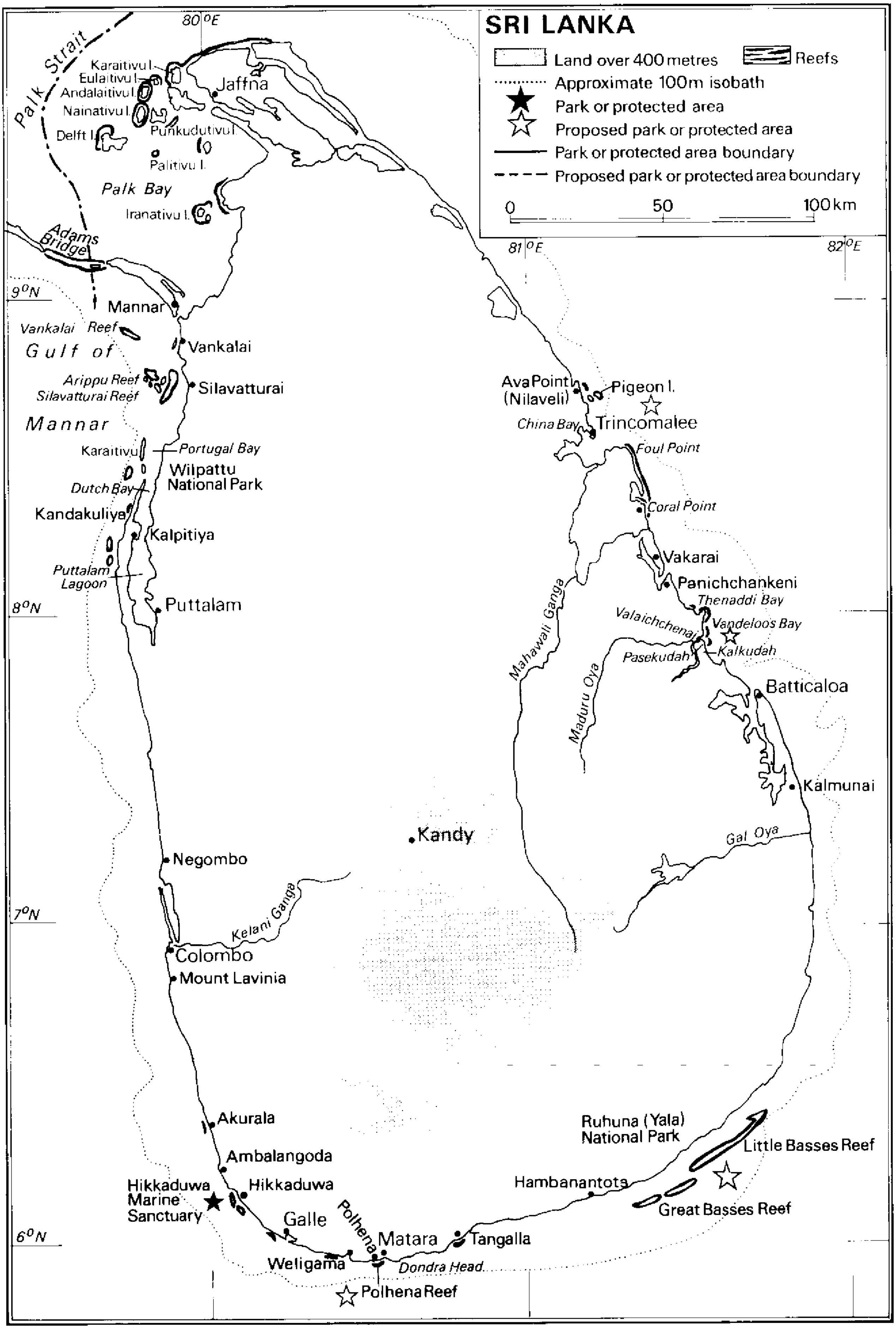
In the south, there are reefs at Akurala, with corals on rocky outcrops and a fringing reef; Hikkaduwa (*see separate account*); Galle and Unawatuna, where there have been extensive fringing reefs; Kapparatota, towards the north end of Weligama Bay; Polhena, near Matara; Dondra Head, where there used to be spectacular rock formations with coral growing on them; on the north-west side of the bay at Dickwella; Nilwella, where several bays had fine corals; and Tangalla, where there used to be a good reef off the headland (Jonklaas *in litt.*, 31.10.84). The status of reefs from Kandakuliya south to Tangalla has recently been assessed by NARA (De Silva, 1986a).

The eastern coast is reported to have the most extensive coral areas. The offshore Basses Reefs in the south are considered to be perhaps the most spectacular in the country (Hoffmann *in litt.*, 15.1.85). There are many areas of fringing reef around Trincomalee, including Pigeon Island, Nilaveli (Ava Point), Poduwakattumalai Bay (off Kuchchaveli), Dutch Bay, Coral Cove and Foul Point. South to Batticaloa (*see separate accounts*) reefs are found at Kalkudah, Pasekudah and Kalavanchikudi, which were once good but are now seriously damaged (Jonklaas *in litt.*, 31.10.84). Panichchankeni to the north of Kalkudah also had a fringing reef (Salm, 1975a). There are excellent formations 300-600 yds (274-549 m) off Kalmunai which extend in large patches north to Batticaloa.

Six species of turtle exist in Sri Lankan waters or nest on its beaches: the Leatherback *Dermochelys coriacea*, Loggerhead *Caretta caretta*, Olive Ridley *Lepidochelys olivacea*, Hawksbill *Eretmochelys imbricata*, Flatback *Chelonia depressa*, and Green *Chelonia mydas*. Of these, the Olive Ridley is the most abundant, several thousand nesting annually with nesting spread through most of the year and concentrated in the south-west (Groombridge, 1982; UNEP, 1986). The Dugong *Dugong dugon* is found particularly in the north-west coast, between Puttalam Lagoon and the Jaffna Peninsula, where there are extensive seagrass beds (Salm, 1975b). A workshop convened by NARA in 1986 discussed research needs for marine ecosystems including coral reefs, mangroves and seagrass beds (NARA, 1986).

### Reef Resources

The collection of coral reef fish is a substantial business and is described by Wood (1985). The export trade is promoted by the Government and there are probably about 500 people involved. Exports are valued at Rs 20-30 million (over US $ 1 million) a year (Wood, 1985) or 56% of all fisheries export earnings (Salm, 1975b). Collecting is seasonal, depending on the monsoon, and occurs on all coasts. The Painted Coral Shrimp *Stenopus* sp. and the relatively deep water corals *Euphyllia, Cynaria* and *Lobophyllia* are also taken in increasing numbers (De Silva, 1985). Spiny lobster resources are described by De Bruin (1970) and pearl oyster, chank and


SRI LANKA
Land over 400 metres
Reefs
Approximate 100m isobath
Park or protected area
Proposed park or protected area
Park or protected area boundary
Proposed park or protected area boundary
0
50
100km
80°E
81°E
82°E
9°N
8°N
7°N
6°N
Palk Strait
Karaitivu I.
Eulaitivu I.
Andalaitivu I.
Nainativu I.
Delft I.
Punkudutivu I.
Palitivu I.
Jaffna
Palk Bay
Iranativu I.
Adams Bridge
Mannar
Vankalai Reef
Gulf of Mannar
Vankalai
Arippu Reef
Silavatturai Reef
Silavatturai
Karaitivu
Portugal Bay
Wilpattu National Park
Dutch Bay
Kandakuliya
Kalpitiya
Puttalam Lagoon
Puttalam
Ava Point (Nilaveli)
Pigeon I.
China Bay
Trincomalee
Foul Point
Coral Point
Vakarai
Panichchankeni
Thenaddi Bay
Valaichchenai
Vandeloos Bay
Pasekudah
Kalkudah
Mahawali Ganga
Maduru Oya
Batticaloa
Kalmunai
Kandy
Gal Oya
Negombo
Kelani Ganga
Colombo
Mount Lavinia
Akurala
Ambalangoda
Hikkaduwa Marine Sanctuary
Hikkaduwa
Galle
Polhena
Matara
Tangalla
Weligama
Dondra Head
Polhena Reef
Ruhuna (Yala) National Park
Hambanantota
Little Basses Reef
Great Basses Reef

bêche de Mer fisheries are briefly mentioned in UNEP (1986). There is a Fisheries Research Station in Colombo and a number of Fisheries Inspection Stations around the island (Salm, 1975a). The fishing industry is described briefly in UNEP (1986). Reef-based tourism is extremely important in the Hikkaduwa area and used to be important around Trincomalee until the political situation brought tourism in the north and east to a halt. The development of coastal tourism is described in UNEP (1986).

**Disturbances and Deficiencies**

A population explosion of *Acanthaster planci* caused serious problems in the early 1970s (De Bruin, 1972; Salm, 1975a) but there have been no recent infestations (De Silva, 1985).

The human population of over 15 million is increasing rapidly, with consequent rapid changes to the island's economy and environment. Approximately 50% of the population live on the coastal strip, the majority in the south-west and north-east. The principal factors affecting coral areas are quarrying for lime, use of explosives for fishing, collection of coral and shells for sale to tourists and of fish for the aquarium trade and pollution (Hoffmann *in litt.*, 15.1.85; Jonklaas *in litt.*, 31.10.84; Salm, 1975a and b).

Mining of reefs for coral for lime is widespread, but at present is concentrated in the Hikkaduwa area in the south-west where, in 1985, a reported 1400 people were directly engaged in coral mining, with perhaps a further 3600 indirectly dependent on the industry (Hoffmann, 1976, 1977 and *in litt.*, 15.1.85). There are said to be as many as 50 kilns along the stretch of coast between Hikkaduwa and Ambalangoda although many of these use coral mined from inland fossil reefs (De Silva *in litt.*, 7.1.87). Coral areas near Kandakuliya are also exploited and reefs at Akurala, Galle, Unawatuna , Tangalla and sites along the south coast are depleted by coral collecting. Lime manufacture leads to devastation not only of the reefs but also of mangroves and terrestrial forests whose wood is used to fuel the lime kilns. Lime quarrying has also affected reefs on the east coast at Vandeloos Bay, Thenaddi, Kalavanchikudi and Trincomalee. Further details of this industry are given in UNEP (1986).

Modern fishing techniques are causing considerable damage in many areas. The use of bottom-set nylon nets is particularly prevalent in inshore coral areas on the east coast, and involves the flattening of corals and the breaking of all new growth so that nets can be set (Hoffmann *in litt.*, 15.1.85; Jonklaas *in litt.*, 31.10.84; Salm, 1975b). Dynamite fishing is commonly practised on both the east and west coasts (De Silva, 1985) and has damaged reefs on the south coast at Dondra Head; Polhena (near Matara), Kapparatota (in Weligama Bay) and Nilwella (Jonklaas *in litt.*, 31.10.84). Nets used to collect live bait for the bonito and tuna fishery also damage corals, as does the system of using old and damaged nets to catch spiny lobsters. The use of spearguns by ornamental fish collectors is also a problem, although there is little recreational spearfishing (Jonklaas *in litt.*, 15.5.85).

Many aquarium fish collectors and exporters believe that fish are less abundant now but there is no scientific data; Wood (1985) lists species that may be particularly vulnerable to overexploitation. The trade is also wasteful since many fish die in transit and collecting methods requiring the removal or systematic breaking of coral are damaging. Spiny lobster populations have been reduced around the entire coastline (Salm, 1975a). Collection of corals and shells for sale as tourist souvenirs and for export has stressed reefs in resort areas in the south-west and east (De Silva, 1985). Corals are sold to tourists in Galle, but in 1986 (Wells pers. obs., 1986) there was little evidence of coral selling in Hikkaduwa, reportedly because of improved enforcement of sanctuary regulations.

Turtle numbers have been reduced through habitat loss, hunting and egg-collecting, despite nominal protection. Hoffmann (*in litt.*, 15.1.85), however, has noted that most turtles are caught accidentally and are rarely deliberately hunted. The tortoise-shell industry, centred on Galle in the south, has practically ceased but tortoise-shell jewellery and handbags are on sale in many tourist and souvenir shops in Galle, Hikkaduwa and Colombo (Wells pers. obs., 1986). Salm (1975b) reported that deliberate Dugong hunting had ceased although there was some accidental catch in large mesh nets and some were killed by explosives used in fishing. Salm (1975a) reported that mining of mineral sands from beaches had led to considerable destruction of turtle nests.

Boat anchoring and possibly the discharge of waste oil may have contributed to coral damage in some lagoonal areas (De Silva, 1985). Tourist pressure has certainly contributed to the decline of reefs in several areas in the south-west and north-east, although over the last year the tourist industry has undergone a noticeable decline due to the political situation. An important source of pollution in the south, where many reefs have been damaged, is the habit of soaking coconut husks in shallow water for the fibre industry (Jonklaas *in litt.*, 31.10.84). There is no information on the impact of silt-laden freshwater run-off or other effluent discharges. Further information on pollution sources is given in UNEP (1986). At Tangalla, the reef at the headland has been damaged by the construction of the fisheries harbour (Jonklaas *in litt.*, 31.10.84).

**Legislation and Management**

Legislation relating to marine resources includes the National Environment Act (No.47 of 1980) and the National Aquatic Resources Research and Development Agency Act (No. 54 of 1981). A detailed account of environmental management and planning for the coastal and marine zone is given in UNEP (1986). Enforcement is a major problem (De Silva, 1985). The National Aquatic Resources Agency (NARA) is taking the lead in reef conservation and has an active programme described by De Silva (1986a).

The Fisheries Ordinance protects spiny lobsters which are berried, soft-shelled or undersized. Use of dynamite for fishing is illegal and, under Fisheries Amendments Law 20 of 1973, it is also illegal to possess fish killed by dynamite or poison. The legislation is inadequately enforced (De Silva, 1985; Salm, 1975b) but NARA, under the Ministry of Fisheries, is currently investigating means to improve this. An attempt by the Government to ban export of live fish was abandoned due to protests by exporters who claimed that some 50 000 people were dependent on the industry although less than 500 are probably involved. Wood (1985) gives recommendations for the improved management of the trade. The import of spearfishing guns is prohibited (Jonklaas *in litt.*, 15.5.85). There are ordinances to regulate fishing of chanks and pearl oysters (UNEP, 1986).

Specific legislation used to exist under the Crown Lands Ordinance 1929 to prevent the removal of coral and other substances from specific areas in the island (from Amblalangoda to Hikkaduwa), but was virtually unenforced. In the 1970s an attempt was made to enforce a ban on coral mining but this was withdrawn due to a claim that 20 000 people would be made unemployed. In 1978, the Coast Conservation Division (CCD) was established within the Ministry of Fisheries, with three sub-components: Planning and Development, Coastal Works and Coastal Research. The Coast Conservation Act, No. 57 of 1981, mandated the CCD to prepare a coastal management programme within three years of the gazetting of implementing regulations and provided the CCD with authority to review permits for all development activities within the coastal zone. Implementing regulations were gazetted in October 1983 and the Coastal Management Plan was to be completed by October 1986 (Anon., 1986). The Coast Conservation Act is designed to protect and preserve the coast from sea erosion or encroachment by the sea and includes the planning and management of development activity within the coastal zone (2 km off shore to 300 m in shore) (Wijewamsa, 1985). It has been used to control coral mining on the east coast to some extent but mining started up again in early 1985 (Hoffmann, 1983). There have also been difficulties of enforcement in other areas, particularly in the west. Amendments to the act were to be put before Parliament in 1985 which would make it illegal to own or operate lime kilns and to use vehicles and equipment for coral extraction within the coastal zone (300 m from shore), infringements being liable to fairly severe penalties and confiscation of equipment. Those engaged in the industry were to be offered alternative employment and/or land for settlement (De Silva, 1985; Hoffmann, 1983). CCD is cordinating with a variety of other agencies whose activities affect the coastal zone. Environmental impact assessments are now mandatory for all major development projects within both public and private sectors (Wijewamsa, 1985).

The main instrument for the conservation of wildlife is the Fauna and Flora Protection Ordinance (1937), which is revised and updated from time to time. It regulates and establishes a series of protected areas which include Nature Reserves, Sanctuaries, Strict Nature Reserves and Buffer Zones. It also regulates hunting, which is now illegal for most species of wildlife and the Dugong is totally protected under the Amendments Act of 1970. Penalties are often very low, and many destructive practices continue (Hoffmann, 1976 and 1983; Salm, 1975a). On the east coast, Pigeon Island and Trincomalee Naval Headworks are both protected areas (*see account for* Trincomalee Reefs) although marine areas are not yet included. On the west coast, Wilpattu National Park, just north of Puttalam Lagoon includes a coastal area and the Dutch Bay area off this region was reportedly made a Marine Sanctuary in 1982, although in 1985 it was still being recommended for protection (Thorsell, 1985). This area probably does not include coral reefs. Regulations for a spiny lobster reserve near the Mount Lavinia Hotel were drawn up but this area was never gazetted (*see separate account*) (De Silva, 1985). Hikkaduwa Marine Sanctuary was declared in 1979 and is the only officially protected reef area in the country, although regulations are poorly enforced and fishing is permitted (*see separate account*).

**Recommendations**

Cabinet approval was granted in July 1980 to the Ministry of Fisheries to enact the necessary regulations under the Fisheries Ordinance to declare Hikkaduwa Harbour Area (also recommended as a Marine Park), Polhena Reef (south coast, near Matara), Great and Little Basses (also recommended for inclusion within Ruhuna (Yala) National Park), Pasekudah and Kalkudah Bay (east coast) and Pigeon Island (Trincomalee) as Marine Sanctuaries and these are now being prepared (*see separate accounts* for all areas except Polhena). Thenaddi Bay has also been recommended for protection (*see separate account*). NARA set up a Working Group on Marine Parks and Sanctuaries in 1982 which has made a number of recommendations; the establishment of Hikkaduwa as a marine park is considered a priority (De Silva, 1986a).

Since several Government agencies hold jurisdiction over the marine environment at the present, there is a need for the establishment of a separate authority with particular expertise and for local participation in the management of reserves. There should be collaboration with the tourist industry in the planning of zones and reef use. There is a particular need for environmental education on marine issues (De Silva, 1985). Other general recommendations for management of the coastal zone are discussed in UNEP (1986). Priorities for research on the Sri Lankan reefs are given in De Silva (1986b).

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## GREAT AND LITTLE BASSES REEFS PROPOSED MARINE SANCTUARY

**Geographical Location** South-east coast, off Yala (Ruhuna) National Park.

**Physical Features** Two areas of rocky ridges, the Great and Little Basses, lying at a south-easterly angle to the coast.

**Reef Structure and Corals** The reefs extend over many kilometres of rocky ridges.

**Noteworthy Fauna and Flora** No information.

**Scientific Importance and Research** Considered the most spectacular reefs in Sri Lanka (Hoffmann, 1983; Salm, 1975b). They merit special attention as they are largely undisturbed.

**Economic Value and Social Benefits** Their tourist potential is probably limited as they can be visited easily only for a few weeks of the year, in April before the onset of the south-west monsoon (Hoffmann, 1985; Salm, 1975c). Each reef has a lighthouse.

**Disturbance or Deficiencies** The reefs have reportedly been damaged by SCUBA divers from Naval ships (Jonklaas *in litt.*, 15.5.85).

**Legal Protection** None.

**Management** None.

**Recommendations** Salm (1975b, c and 1981) recommended that Yala (Ruhuna) National Park be extended off shore to include the Basses Reefs. Cabinet approval was granted in July 1980 for the Ministry of Fisheries to enact the necessary regulations under the Fisheries Ordinance to declare Great and Little Basses as Marine Sanctuaries (De Silva, 1985).

## HIKKADUWA MARINE SANCTUARY AND PROPOSED MARINE PARK

**Geographical Location** South-west tip of Sri Lanka, north of Galle; 6°08'N, 80°05'E; includes Rocky Islets Sanctuary at 6°09'N, 80°08'E.

**Area, Depth, Altitude** 45 ha, including Rocky Islets Sanctuary of 1.2 ha; reef less than 3 m deep (Salm, 1975a).

**Land Tenure** No information.

**Physical Features** From the shore, the Hikkaduwa reefs extend about 130 m seawards before dipping sharply down to soft substrate at about 7-10 m. The outer edge of the reef flat in the north receives strong wave action, as do the shallower terraces of the reef flat in the south. Where a lagoon or channel exists behind the reef flat and to shoreward of patch reefs, water movement is less and shows an overall longshore current caused by the pumping action of the waves. Water clarity throughout the shallow reef slopes is high and illumination is well above that needed for algal growth (Mergner and Scheer, 1974). The Rocky Islets form a small cluster of rocks, several hundred yards off shore, devoid of vegetation.

**Reef Structure and Corals** The reefs were first described by Mergner and Scheer (1974). The northern reef is described as a lagoon reef, since a 3-4 m deep channel with good coral cover separates the reef crest from land. The reef flat differs from the one in the south as it is less than 1 m deep. Near shore, there is a narrow band of seagrass before a *Halimeda* zone. Towards the gradually deepening lagoon, coral diversity increases and *Montipora* is dominant until the deepest point at about 3-4 m is reached. *Acropora* then increases and characterizes two more zones, either alone or with alcyonarians. The lagoon becomes more shallow towards the outer edge of the reef flat on which *Favia* is the commonest genus. The reef flat is penetrated by channels which sometimes extend through its entire width and may form a spur and groove system. On the seaward reef slope, *Acropora* is the most conspicuous genus, with the alga *Caulerpa* in the shallowest region. The reef slope extends to only about 7 m before giving way to soft substrate (Mergner and Scheer, 1974).

The southern reef is more typical, apart from three steps or terraces which dip seawards. The upper step borders onto the eulittoral and is composed of beach rock, which has been abraided by debris and covered with algae, and lacks living corals. The outer edge of this step is bordered by a *Sargassum* zone. The middle step is about 25 m broad, extends to about 1-1.5 m, and has live coral colonies and many sand-filled hollows. Coral genera include *Pocillopora, Acropora, Montipora, Porites, Favia, Favites, Goniastrea* and *Platygyra*. The algae *Halimeda* and *Caulerpa* are also common, particularly the former whose abundance typifies the zone. A short drop leads to the outermost step or hydroid zone which has scattered living coral heads of the same genera, plus *Sandalolitha* and abundant hydroids. The outer edge of this step and the seaward reef slope form a series of pillars and buttresses that descend from 4 to 12 m. Sand-filled gullies may penetrate as far shorewards as the middle step about 50 m inwards from the edge of the reef. Fans of coral rubble and sand extend from the gullies onto the more gently sloping region below the reef slope. There is no strong zonation of corals on the reef slope. There are also several patch reefs which rise to the surface in this area (Mergner and Scheer, 1974).

Hughes (1985) provides some observations on the reefs. A survey in 1985 found that the reef lagoon area in the Sanctuary had 18% live hard coral cover, 8% coral rubble and 29% dead coral. Soft corals covered 40% of the reef slope. De Silva and Rajasuriya (1985) recorded 60 species of hard coral.

**Noteworthy Fauna and Flora** De Silva and Rajasuriya (1985) recorded 68 species of fish within the Sanctuary.

**Scientific Importance and Research** These are the only reefs in Sri Lanka which have been treated to a detailed biological study (Merger and Scheer, 1974) and in 1985 they were surveyed by the National Aquatic Resources Agency (De Silva and Rajasuriya, 1985). They were once visited by a student cruiseship (Jonklaas, 1981), but educational use of the reefs has lapsed.

**Economic Value and Social Benefits** This area receives numerous visitors as Hikkaduwa is a major tourist resort with about 150 hotels along the sea front. There are at least three dive operators (Hughes, 1985), organised boat tours, excursions and glass-bottom boats (Jonklaas, 1981).

**Disturbance or Deficiencies** Reefs in the lee of the Rocky Islets Sanctuary were intact and flourishing in 1981, but there was some damage from recreational activities (Jonklaas, 1981). Salm (1975b) noted a paucity of small, colourful reef fish of the type caught extensively for the aquarium trade. Fish collecting was taking place in the 1970s in the sanctuary area and still occurs, causing significant damage (De Silva and Rajasuriya, 1985). Hoffmann (*in litt.*, 15.1.85) suggests that visitor impact on the reefs is not severe, although damage to corals by breakage is evident (Hughes, 1985). Local shops, hotels and people sell shells and corals and there has been noticeable overcollecting on the reefs (Hoffmann *in litt.*, 15.1.85; Jonklaas, 1981). Spiny lobster have also been overcollected (Jonklaas, 1981). Live coral colonies are reportedly still collected by glass-bottom boat operators for sale to customers onboard (De Silva, 1985), although corals no longer seem to be sold on the beach (Wells, pers. obs., 1986). Spearfishing is common (Hughes, 1985) and the larger territorial fish are said to be scarce (Jonklaas, 1981). Coral quarrying is extensive in the region and many of the buildings use crushed corals as a hard standing (Hughes, 1985); erosion of the coast is becoming a serious problem. Large numbers of fishing and glass-bottom boats are anchored in the reef lagoon and have damaged the reefs and corals through anchoring and pollution. Coral damage has also been recorded adjacent to a freshwater outlet polluted by coconut husk retting (De Silva and Rajasuriya, 1985).

**Legal Protection** The Hikkaduwa Marine Sanctuary was declared on 18 May 1979 under Section 2(2) of the Fauna and Flora Protection Ordinance (Chapter 469) as amended by Act No. 44 of 1964 and Act No. 1 of 1970. Removal of coral, sand or other substance from the area is prohibited under the Crown Lands Ordinance, Sections 63 and 66 (De Silva, 1981). Fish have no legal protection. The Rocky Islets (Ambalangoda/Hikkaduwa) Sanctuary was established on 25 October 1940 under the Fauna and Flora Protection Ordinance, Gazette No. 8675, but covers only the terrestrial parts of these islands.

**Management** The sanctuary boundaries were once demarcated (somewhat randomly) by buoys but these were swept away and had not been replaced by 1975 (Salm, 1975a). Supervision of the sanctuary should be the responsibility of the village council and under the authority of the Dept of Wildlife Conservation but there is currently no wardening (Wells pers. obs., 1986). A sign in the grounds of the Coral Gardens Hotel prohibits spearfishing and coral and shell collecting. Hughes (1985) reports that the Reserve is mentioned in tourist leaflets but otherwise is not publicised. In early 1986, some fishermen using dynamite were apprehended as a result of action taken by one of the commercial diving operators.

**Recommendations** Cabinet approval was granted in July 1980 to the Ministry of Fisheries to enact the necessary regulations under the Fisheries Ordinance to declare the Hikkaduwa Harbour Area as a Marine Sanctuary. The first steps towards establishing a Marine Park have been taken by the National Aquatic Resources Agency, and the views of the members of the National State Assembly are being sought. Jonklaas (1981) recommended the banning of spearfishing and poling of boats, the establishment of permanent moorings, the cessation of visits to the Rocky Islets Sanctuary in order to prevent damage to the surrounding reefs and to encourage seabirds to return, and the restocking of the reefs with fish where these have been collected for the aquarium trade. De Silva and Rajasuriya (1985) provide recommendations for management and stress that it will be more appropriate to manage the area as a Marine Park, accessible to the public, rather than as a Marine Sanctuary. Three Zones have been recommended, two for general use (one of which would cover the Rocky Islets Sanctuary) and one for research. Details are given in De Silva and Rajasuriya (1985) with a number of other suggestions for management of the area. These should be implemented as soon as possible. There is an urgent need for a public awareness campaign to alert hoteliers in the area to the problems of reef conservation and to the purpose of the sanctuary, and considerable scope for a marine conservation interpretive programme for tourists and local people alike. Some form of wardening is essential and the sanctuary boundary should be marked again, preferably with fixed markers on land rather than buoys.

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## KALKUDAH AND PASEKUDAH PROPOSED MARINE SANCTUARY

**Geographical Location** East coast; district of Batticaloa, south of Vandeloos Bay; 7°59'N, 81°33'E.

**Area, Depth, Altitude** 30 cm-4 m.

**Physical Features** There is a long sweep of sandy beach, with reef fringing the promontory separating Kalkudah from Pasekudah. Water clarity exceeds 10 m in the south-west monsoon but decreases with the north-east monsoon. Water temperature is 27-29°C. Currents are tidal round the reef; inshore surface currents are wind-induced. Tidal range is under 1 m. Winds are north-easterly from November to February and south-westerly from May to September (Salm, 1975b).

**Reef Structure and Corals** The back-reef lagoon is dominated by *Thalassia-Thalamita*. The reef flat has a *Padina-Caulerpa* talus (ramose *Acropora* fragments) assemblage. The reef crest consists of an *Acropora-Caulerpa* community at Kalkudah and a massive corals-*Caulerpa* community at Pasekudah (Salm, 1975b).

**Noteworthy Fauna and Flora** Salm (1975b) briefly lists the marine fauna and flora. The Hawksbill Turtle *Eretmochelys imbricata* has been recorded.

**Scientific Importance and Research** Surveyed briefly by Salm (1975b) who considered it the finest fringing reef in the Eastern Province.

**Economic Value and Social Benefits** There is potential for recreational activities, and fishing is important.

**Disturbance or Deficiencies** Considerable areas of back-reef coral rock have been removed for the lime industry. A hotel at Pasekudah may have increased recreational impact, and effluent from a paper factory near Valaichchenai may be damaging. Jonklaas (*in litt.*, 31.10.84) considers that the reefs at Kalkudah and Pasekudah are now seriously damaged.

**Legal Protection** None.

**Management** None.

**Recommendations** Recommended for protection by Salm (1975a). Cabinet approval was granted in July 1980 for the Ministry of Fisheries to enact the necessary regulations under the Fisheries Ordinance to declare this area a Marine Sanctuary (De Silva, 1985).

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## MOUNT LAVINIA LOBSTER "RESERVE"

**Geographical Location** West coast, between Mount Lavinia Hotel and the Galle Buck Lighthouse, Colombo.

**Area, Depth, Altitude** 13 km stretch of reef.

**Physical Features** Two parallel rocky reefs on sandstone follow the coastline with discontinuous deeper rocks; the inner reef is emergent at low tide; the deeper reef is at 12-16 m. Visibility up to 10 m. Water temperature 24-29°C. Tidal range under 1 m. Winds are north-easterly from November to March and south-easterly from May to September (Salm, 1975a).

**Reef Structure and Corals** Sabellariid worms *Pallasia pennata* are important in the construction of the shallower reefs within the "Reserve" (Salm, 1975a).

**Noteworthy Fauna and Flora** A description of the marine flora and fauna is given in Salm (1975a). The densest remaining concentration of spiny lobster *Panulirus versicolor* was found in this area in the 1970s.

**Scientific Importance and Research** None.

**Economic Value and Social Benefits** Mount Lavinia is now a suburb of Colombo and the coast is heavily developed. It is popular as one of the closest recreational areas to the capital, with several hotels. The Reserve was established in the hope that the population of spiny lobsters could be protected as a breeding stock (Salm, 1975a).

**Disturbance or Deficiencies** In the early 1970s removal of lobsters was continuing quite openly, and undersize lobsters were taken (Salm, 1975a). Current status of the lobster population is unknown.

**Legal Protection** Regulations were drafted in 1973 by the Ministry of Fisheries to declare this area as a Lobster Reserve under the Spiny Lobster and Prawn (Shrimp) Regulations of the Fisheries Ordinance Section 33. There is no evidence that regulations were ever gazetted.

**Management** None.

**Recommendations** This area is no longer considered of major importance, but is described here because of the confusion in the literature over its protection status.

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## THENADDI BAY

**Geographical Location** Batticaloa District, east coast, from Elephant Point to Velikudah Periya Munai Point; 7°59'N, 81°31-81°33'E.

**Area, Depth, Altitude** 2-6 m deep off the reefs.

**Physical Features** Reef fringes Velikudah Periya Munai Point and stretches from Pulavi to Elephant Point. There are patches of reefs in the bays. Visibility exceeds 10 m; water temperature is 27-29°C. Currents are tidal around the reefs but off shore vary with the wind. Tidal range is less than 1 m. Winds are north-easterly from November to February and south-westerly from May to September (Salm, 1975b).

**Reef Structure and Corals** The back-reef lagoon has a community of *Padina, Acropora* and *Pocillopora*. The reef flat is predominantly *Halimeda* and *Caulerpa*. The reef crest is dominated by digitate *Acropora* and the reef front has a community of *Porites, Astreopora, Favia, Echinopora* and *Acropora*. There are large boulders of *Porites* and *Astreopora* off Pulavi Point (Salm, 1975b).

**Noteworthy Fauna and Flora** Salm (1975b) gives a brief description of the marine fauna and flora of the area. Waders and herons are abundant; White-shafted Little Terns *Sterna albifrons sinensis* and Roseate Terns *S. dougalli* nest on the cay off Velikudah Periya Munai Point and the Blue Rock Pigeon *Columba livia intermedia* nests on Elephant Rocks.

**Scientific Importance and Research** Surveyed briefly by Salm (1975b).

**Economic Value and Social Benefits** Fishing, including aquarium fish collecting is important. The area is sparsely populated but fishermen converge there during the south-west monsoon (Salm, 1975b).

**Disturbance or Deficiencies** Dynamiting and *Acanthaster planci* have caused problems. Coral mining was a major issue: at the small settlement of Kayankeni, lime kilns in operation in the 1970s used about half a million cu. ft (14 000 cu. m) of coral each year and an equal volume of firewood cut locally. The local fish catch had almost ceased as a result of damage to reefs and mangroves, and forests in the area had been almost completely destroyed (Hoffmann, 1976).

**Legal Protection** None.

**Management** None.

**Recommendations** Recommended for protection by Salm (1975a and c).

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## TRINCOMALEE REEFS INCLUDING AVA POINT (NILAVELI) AND PIGEON ISLAND PROPOSED MARINE SANCTUARY

**Geographical Location** East coast; 8°33'-43'N; 81°10'-81°13'E. Pigeon Island lies 2.6 km off shore and 16 km north of Trincomalee.

**Area, Depth, Altitude** Inner harbour at Trincomalee c. 20.25 sq. km; depth 30 cm-80 m (in channels); depth at Ava Point 0.5-8 m; depth at Pigeon Island 0.5-12 m.

**Physical Features** These reefs are sheltered for most of the year and have relatively good visibility, up to 10 m and exceeding 12 m at Pigeon Island. Trincomalee Harbour is a naturally sheltered bay with coves, rocky outcrops and small islands including Great and Little Sober Islands. Ava Point (Nilaveli) is a line of rock running east from the shore north of the lagoon mouth as far as a low island surrounded by coral reef. Pigeon Island is small and wooded, surrounded by reefs (Salm, 1975b).

Currents in the harbour at Trincomalee are related to tides and winds, with surface water flowing out during November and December, following heavy rainfall, and deep water (20 m) flowing in. Along this stretch of coast, winds are north-easterly from November to February and south-westerly from May to September. Tidal range is under 1 m (Salm, 1975b).

**Reef Structure and Corals** Trincomalee Harbour has a largely sandy and rocky substrate, the latter supporting some faviid-*Porites* assemblages. At Ava Point, the reef around the islet consisted in the 1970s of a ramose *Acropora* assemblage with *Echinopora lamellosa, Porites, Symphyllia*, faviids and *Pocillopora*. An *Acropora - Echinopora* assemblage was found on banks about 100 m from the islet with colonies of *Hydnopora exesa* (uncommon around Sri Lanka). The northern side of Pigeon Island had an assemblage of tabular *Acropora* and *Pocillopora verrucosa*; the western side had an *Echinopora lamellosa* - digitate *Acropora* assemblage; the southern side had a ramose *Acropora* assemblage (60% of which was dead in 1975) and the eastern side fell off steeply with no coral. Pigeon Island at that time had some of the best coral reef in the country (Salm, 1975b).

**Noteworthy Fauna and Flora** Salm (1975b) describes coastal vegetation in this area. At Trincomalee there is abundant bird life (nesting White-bellied Sea

Eagles *Haliaeetus leucogaster*, roosting cormorants Phalacrocoracidae), Wild Boar *Sus scrofa*, Spotted Deer *Cervus axis*, and Grey Langur *Presbytis entellus*. Ava Point has a number of nesting terns as well as a variety of waders. The Blue Rock Pigeon *Columba livia intermedia* nests at Pigeon Island. The spiny lobster *Panulirus versicolor* occurs at Ava Point.

**Scientific Importance and Research** Surveyed briefly by Salm (1975b).

**Economic Value and Social Benefits** Trincomalee is an important port, being one of the largest safe natural habours. The offshore waters are fished. All three areas were important recreational sites and were visited by divers, snorkellers and fishermen prior to the current political situation. There was a diving centre at Trincomalee. At Ava Point there is a hotel to the south and in 1975 there was a migrant fishing camp to the north (Salm, 1975b).

**Disturbance or Deficiencies** Monsoon storms are implicated in some damage to these reefs. *Acanthaster planci* was present at Ava Point and Pigeon Island in 1975. It was particularly abundant at the latter where hundreds were recorded and there was considerable damage (De Bruin, 1972; Salm, 1975a). Disturbances through dynamiting and coral breaking have been cited as contributory factors in this outbreak, but their impact is the subject of dispute and by 1985 the starfish were reported as having largely disappeared (Hoffmann *in litt.*, 15.1.85).

In 1975, reefs at Ava Point and Pigeon Island were suffering some trampling from visitors. Shell, coral and fish collecting, spearfishing and fishing with dynamite have had an impact. Coral Cove at Trincomalee was affected by coral mining for lime (Jonklaas *in litt.*, 31.10.84; Salm 1975a, b and 1979) but this activity has now been curtailed. Coral assemblages adjacent to Trincomalee Harbour were potentially threatened in the 1970s by further port and tourism development, the former taking place particularly in the China and Cod Bay areas. There have been recent reports of serious damage from boats crashing onto the reef to unload visitors, who then trample the corals. It is reported that, with the coral gone, all that is left of the formerly rich reef life is a few sea cucumbers and starfish (Anon., 1984). Intensive collection of fish for the aquarium trade has taken place on the Trincomalee Reefs. Spearfishing has had a notable impact on the populations of larger, territorial fish species.

**Legal Protection** Pigeon Island was established as a Wildlife Sanctuary in 1974 but protection does not extend to the marine environment. Similarly Trincomalee Naval Headworks Sanctuary and Great and Little Sober Islands Sanctuaries, all of which were established in 1963, do not include reefs.

**Management** No information.

**Recommendations** Salm (1975a) recommended protection for the reefs at Ava Point and Pigeon Island. Cabinet approval was granted in July 1980 for the Ministry of Fisheries to enact the necessary regulations under the Fisheries Ordinance to declare Pigeon Island a Marine Sanctuary (De Silva, 1985). A reef survey of this area was planned for 1985 (UNEP files).

# SUDAN

## INTRODUCTION

### General Description

Including bays and inlets, Sudan has a total coastline of about 750 km, lying between 18°N and 22°N. The widest part of the Red Sea (306 km) and the deepest reading (3040 m) for the central trough lie off Port Sudan (Salih 1976; Schroeder, 1982a and b). Schroeder (1982a and b) describes the hydrology and oceanography of the Sudanese Red Sea. Rainfall averages 111 mm a year, and falls mainly in November and December. Sea surface temperatures at Port Sudan range from 26.2-30.5°C, but may be higher in shallow or enclosed coastal waters and in the hot brines of deep basins. At 150 m depth the range is still 23.9-25.9°C and the minimum temperature is 21.6°C. Salinities range from 38 to 41 ppt and may be higher in shallow or enclosed waters and in deep basins. Winds are normally northerly. From November to April surface currents flow northward and for the rest of the year they flow southwards. Nearshore currents generally follow the local wind pattern. Tidal range is about 55 cm, and water transparency is high. Geological and sedimentary aspects of several offshore areas are described by Braithwaite (1982).

Much of the coast is bordered by fringing reefs, 1-3 km wide and in a few metres of water, with occasional deep depressions (25 m or more) such as those north of the harbour entrance at Port Sudan and interruptions at the extrances to mersas (coastal lagoons) and the Tokar Delta. Separate accounts follow for the Gebel Elba area (in the Sudan Government Administration Area), Mukkawar Island and Dunganab Bay, and Port Sudan. The reef at Shaab Baraja, due east of Mohammed Qol, is described by Schroeder (1980c). Barrier reefs, 1-14 km wide, parallel much of the coast, separated from the fringing reefs by a 2-5 km wide channel, 100-400 m deep. These occur as a series of inner and outer reefs separated by a largely coral-covered bottom ranging from a few to several tens of metres in depth. The outer barrier reefs drop to several hundred metres. The Towartit Reefs lie to the south, and the Wingate Reefs to the north of Port Sudan.

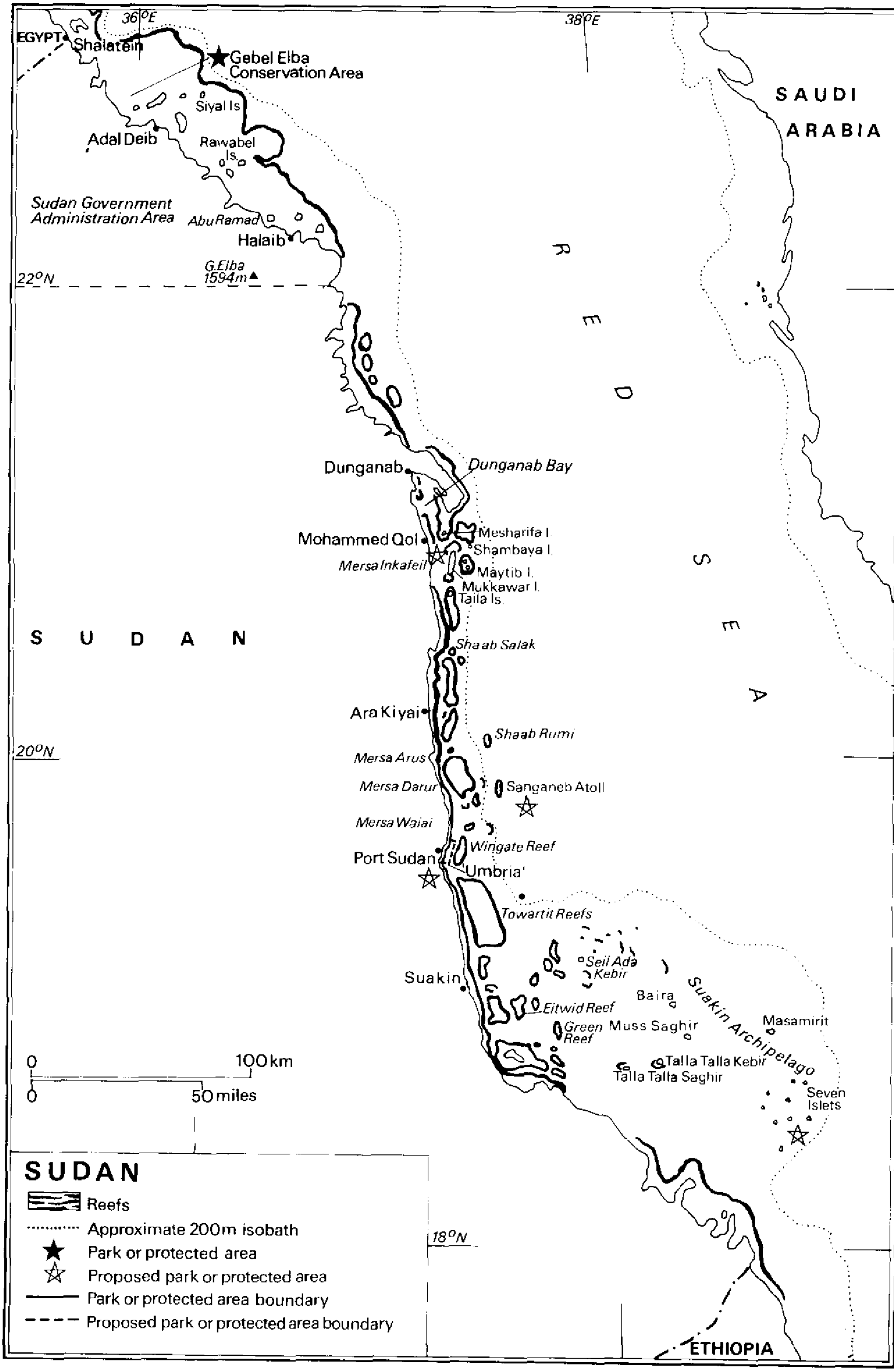
Reefs inside the outer barrier in and near the Towartit reef complex off Port Sudan were described by Vine and Vine (1980). Transects were made from the wrecked ship "Mani" towards Port Sudan's large grain elevator, and on the north-west side of a shallow patch reef within the area protected by the North Towartit beacon reef, on the south-east side of Red Beacon reef in the Towartit reef complex, on Harvey Reef, on Little Harvey Reef (a small patch reef south of Harvey reef) and on the north-east side of Laurie reef. Coral fauna was poor with much algae and soft corals, and limited marine life in several localities. Head (1980a and b) and the Cambridge Coral Starfish Research Group carried out studies on reef communities on the Towartit reefs (Schroeder, 1978).

Reefs forming the outer barrier were surveyed at the most southerly point of Wingate Reef and on the east side of Wingate barrier reef, 1 km south-east of North Wingate beacon (Vine and Vine, 1980). Numerous patch reefs are found in shallow water which tend to support particularly rich coral growth. Further off shore there are atolls with steep drop-offs to 400-800 m, such as Sanganeb (*see separate account*) (Schroeder, 1982a and b). The reefs of the Suakin Archipelago are described in a separate account.

Sudan has some of the richest reefs in the Red Sea (Ormond, 1976), with species diversity approaching its maximum due to widely varying physical and biological parameters (Vine and Vine, 1980). However, in contrast to many other Red Sea coral reefs, those of the Sudan lack clear patterns of zonation. Coral checklists have been compiled by Head (1980a), Mergner and Schuhmacher (1985b), and Schroeder and Scheer (1981). The corals of Sanganeb (71 species), collected by Schroeder, and those of Wingate Reef (also 71 species), collected in 1962 by Scheer during an expedition by the Hessisches Landesmuseum, Darmstadt, are listed in Scheer and Pillai (1983). Some noteworthy species were described separately (Scheer, 1964).

Molluscs are described by Mastaller (1978) and the biology of pearl oysters by Nasr (1979). Fish are described by Edwards and Roswell (1981) and Vine and Vine (1980). The Red Sea endemic *Paracheilinus octotaenia* (Labridae) occurs on Sudan's deep water reefs (Ormond, 1980b). The Humbug Damselfish *Dascylus aruanus* was studied at Port Sudan and at the Suakin Marine Laboratory (Coates, 1980). Algae are described by Dufalla and Karim (1980). Hawksbill Turtles *Eretmochelys imbricata* nest on offshore islands, mainly in the Suakin Archipelago, and Green Turtles *Chelonia mydas* are sometimes seen. There is a single record of an Olive Ridley *Lepidochelys olivacea* (Groombridge, 1982; Hirth and Latif, 1980; Moore and Balzarotti, 1976). Dugong *Dugong dugon* have been recorded at a few sites and there is an estimated total population of 20-40 (Ormond, 1980a). Cooper *et al.* (1984) list seven species of seabirds, including four species of tern *Sterna* spp., the Brown Noddy *Anous stolidus*, and two species of gull *Larus* spp., which breed in the Suakin Archipelago and the Mukkawar, Taila and Maytib Islands; details are given in Moore and Balzarotti (1983).

Pioneering work was carried out by Crossland (1907, 1911 and 1913) and work on the Sudanese reefs is summarized in Mergner (1984). Vine and Vine (1980) described 30 selected reef sites, including communities on Towartit, Shaab Salakh and Shaab Shinab. Cousteau carried out an experiment in underwater living at Shaab Rumi to the north of Port Sudan (Diolé and Falco, 1976; Vine and Vine, 1980). Following the experiment, studies were carried out on the establishment and growth of marine life on the remaining pieces of equipment which were left underwater (Vine and Head, 1977). The Saudi-Sudanese Red Sea Commission was created in 1974 to investigate metalliferous deposits in the axial trough of the Red Sea between the two countries, and to study their possible exploitation. Processing the mud which is produced in the course of deep sea mining poses physical and chemical threats to the adjacent reefs in the form of possible increased turbidity (Schroeder, 1978, 1982a and b) and therefore a research programme was established in 1976 which included a reef survey along the Sudanese


36°E
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Shalatein
Gebel Elba
Conservation Area
Siyal Is
Adal Deib
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S U D A N
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Sanganeb Atoll
Mersa Waiai
Wingate Reef
Port Sudan
Umbria'
Towartit Reefs
Seil Ada
Kebir
Suakin
Baira
Suakin Archipelago
Eitwid Reef
Green
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Muss Saghir
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SUDAN
Reefs
Approximate 200m isobath
Park or protected area
Proposed park or protected area
Park or protected area boundary
Proposed park or protected area boundary

coast (Nawab, 1980). The University of Hamburg and the Institute of Oceanography have studied the reefs at Shaab Baraja (Betz and Otte, 1980; Schroeder, 1980c).

The joint ECA (Economic Commission of Africa)/Unesco project to develop marine science includes Sudan (Morcos, 1980). Research centres include the Institute of Oceanography of the National Council for Research in Port Sudan (which has set up pollution monitoring transects), the Fisheries Research Centre of the Agricultural Research Corporation in Port Sudan (fishing, mariculture, especially pearl oysters), the Suakin Marine Biological Laboratory of the University of Khartoum and the Environmental Studies Institute of the University of Khartoum. Following a suggestion that they should be amalgamated into the Marine Science Faculty of the University of the Eastern Region (Schroeder, 1982a), a national research plan has been developed which includes conservation and pollution monitoring studies (Nasr, 1985). The work of the Institute of Oceanography is described by Schroeder (1977 and 1980b). ALECSO is providing support for a marine research station (Rifai, 1980).

**Reef Resources**

The Sudanese have little traditional dependence on the sea; fish consumption is low, turtles and Dugong are not hunted and dynamite fishing is unknown (Schroeder, 1981c). About 350 fishermen from six communities along the coast use 150-270 boats, and the principal method is handlining, although trolling is becoming more popular. The total catch was between 300 and 600 tons per year between 1973 and 1979 and was sold mainly in Port Sudan (Reed, 1964a; Schroeder, 1982a and b; Schroeder *et al.*, 1980a). Shrimps (2-3 tons), holothurians and sponges are also taken. The lobster fishery is described by Sanders (1973). *Panulirus penicillatus* is the commonest species taken but *P. ornatus* and *P. versicolor* may also be caught. *Pinctada margaritifera*, both natural and cultivated, is exploited for buttons, although the annual harvest has now declined to 5 tons. Research into its cultivation is currently underway (George *et al.*, 1984). *Trochus dentatus* is collected for export although catches are declining. Dufra perfume is made from crushed gastropod operculi, one pound of which needs 1000-2000 operculi. In Port Sudan about 13 lbs are sold a day; some of the gastropods are imported but there is some local collecting (Schroeder, 1982a and b). Schroeder (1982a and b) also reviews the non-living resources of the Sudanese Red Sea.

Coral reefs are the main tourist attraction and marine recreation is also enjoyed by residents (*see accounts for* Sanganeb and Port Sudan) (Schroeder, 1978). From 200 to 500 divers visit Sudan each year. Popular diving sites include the wreck of the *Umbria*, Shaab Rumi and Sanganeb Atoll. The economic potential of diving and tourism is not yet fully exploited (Schroeder, 1982a).

**Disturbances and Deficiencies**

*Acanthaster planci* outbreaks have occurred on the reefs since the early 1970s and were studied in the course of a series of expeditions by the Cambridge Coral Starfish Research Group (Moore, 1985; Ormond and Campbell, 1974; Roads and Ormond, 1971). In 1970 high densities were recorded on patch reefs near Port Sudan but did not in the long term cause significant damage. Fluctuations in population size and the occurrence of mini-aggregations appear to depend on availability of food, shelter and the physical conditions of the environment. Their main predators are probably *Arothron hispidus* (pufferfish), *Pseudobalistes flavimarginatus* and *Balistoides viridescens* (triggerfish), and overcollecting of these fish could have contributed to the outbreaks. In 1970, densities of up to 1000/ha were found on two reefs in the Towartit complex and these continued to be as high at least until 1974. Such high densities may also have been partly the result of increased eutrophication due to waste (Ormond and Campbell, 1974).

Threats to the Sudan reefs are largely limited to the Port Sudan area (Schroeder, 1981c and 1983). Tourists are damaging the reefs with rubbish and careless anchoring (Salih, 1976; Schroeder, 1982a and b). Within one week of opening the first tourist village at Mersa Arus, north of Port Sudan, over a ton of fish was brought to market by tourist fishermen (Ormond, 1976). Many of the corals at Shaab Rumi, Cousteau's underwater habitat site, have been damaged by recreational divers (Vine and Vine, 1980). Heavy spearfishing, especially at Towartit, and collecting of coral and shells, particularly by sailors, may have had an impact in the past (Kundaeli, 1978). Pollution is becoming an increasing problem (Schroeder, 1982a and b) with the increase in coastal industrial plant, shipping, tourism, reclamation and port construction. The Towartit and Wingate Reefs provide the only anchorage for big ships and are subjected to their waste discharge (Ormond, 1978).

Oil or gas reservoirs may occur on the shores and offshore areas of Sudan, similar to those of the Egyptian oil fields on both sides of the Gulf of Suez, and exploration is being carried out. If exploitation is started, pollution could become even more serious. Old Suakin Harbour may be used for coastal shipping again and a new port may be built to the north, at New Suakin, Mersa Kuwai, to relieve some of the pressure on Port Sudan. Baseline studies are still needed, with mapping of individual outfall sites and the monitoring of industrial development (Schroeder, 1978).

**Legislation and Management**

Marine conservation is controlled by the Sudanese Marine Conservation Committee (SMCC), a sub-committee of the National Committee for Environment, which is composed of representatives of the Fisheries and Hydrobiological Research Unit, the Fisheries Production Department, Suakin Marine Laboratory (University of Khartoum), the Seaports Corporation, the Sudan Navy, the Sudan Tourist Corporation, the Geology and Mineral Resources Department, the Institute of Oceanography (IO), the Port Sudan District Council, the Health Authorities and the Port Police. SMCC is basically advisory and supervisory, the IO providing leadership in carrying out the work. Substantial support is received from IUCN and WWF through Project IUCN 1163 "The Conservation of Coral Reefs of the Sudanese Red Sea" (Nasr, 1985; Schroeder, 1978 and 1982a; Schroeder *et al.*, 1980a and b). IUCN/WWF Project 1259 has supported the development of the proposed Sanganeb Marine National

Park (*see separate account*). ALECSO (Arab League Educational, Cultural and Scientific Organisation) has supported much of the work on marine conservation in the country.

Sudan has signed the Regional Convention for the Conservation of the Red Sea and Gulf of Aden Environment (Schroeder, 1982a). The 1975 Environmental Health Act states that no solid, liquid, or gas which may be harmful to man or animal may be put in the sea. Considerable efforts have been made by the SMCC to investigate pollution incidents and advise on waste discharge; it is now consulted whenever a proposed project involves the sea or shore.

Early marine conservation efforts in Sudan included the development of a "Conservation Manifesto" (Cambridge Coral Starfish Research Group, n.d.; Schroeder, 1982a and b). This contributed to the 1975 Amendment of the Marine Fisheries Regulations of 1937, which prohibits the use of spearguns, collection of corals, shells and aquarium fish, and disposal of refuse in the sea (Medani, 1976; Salih, 1976). A local order drafted by the Commissioner of the Red Sea Province authorises officials to search and apprehend offenders at sea and on land, and bans trade in corals, shells and aquarium fish. The sale of marine curios has now almost ceased (Schroeder *et al.*, 1980b). SMCC have drafted a new Marine Fisheries Act and Marine Environment Conservation Act in consultation with IUCN to replace the 1937 legislation (Schroeder, 1981c, 1982a and b; Schroeder *et al.*, 1980b) which has been ratified by the National Cabinet and National Assembly. It includes enabling legislation to permit the establishment of marine parks and reserves, and regulates construction in and near the Sea. Turtles are not protected but are rarely taken (Nasr *in litt.*, 1.2.87).

As yet there are no marine parks or reserves. The Preservation of Wild Animals Ordinance of 1935 (as amended) permits the establishment of National Parks, Game Sanctuaries and Game Reserves (IUCN, 1987). Sudan has agreed to cooperate in the establishment of the Gebel Elba Conservation Area, which lies in the Sudan Government Administration Area (*see separate account*) and is protected under Egyptian law.

In general, the laws are insufficiently known and enforcement is poor, although it has been improved through the co-operation of the police, customs and navy. Confiscated corals and shells have been given to University collections. A public awareness campaign involving leaflets, noticeboards and circular letters has been undertaken. The SMCC has started a number of educational programmes and gives illustrated lectures, visits schools and produces educational postcards (Schroeder, 1982a). A guide to the marine fauna and flora of the Sudanese Red Sea is being produced (Nasr, 1985). A small aquarium in the Institute of Oceanography has been set up and slide shows are being given (Schroeder, 1982a). A large aquarium is being built at Port Sudan (*see separate account*).

**Recommendations**

The following protected areas for coral reefs have been recommended:

- Sanganeb Marine National Park (*see separate account*); considered the highest priority.
- Port Sudan Marine National Park; this would include (or be adjacent to) the proposed Abu Hashish Marine Recreational Centre, which has been suggested as a replacement for the damaged coral gardens (*see separate account*).
- Suakin Archipelago National Park or reserve (*see separate account*).
- Mukkawar Marine National Park: to include Mukkawar Island, Mesharifa and Maytib Islands, outer reefs such as Arlington reef, and the coastal area around Mersa Inkafail (*see separate account*).

Arakiay, between Donganab and Port Sudan, and Arous, further south, have also been recommended for protection but are not considered such high priorities (Ormond, 1976; Schroeder, 1982a). The potential for creating marine reserves in the Port Sudan area, at the site of the *Umbria*, at Wingate Reef, at Shaab Rumi and in the Suakin Archipelago, is being considered by the SMCC (Nasr *in litt.*, 1.2.87).

Proposed research is described in Schroeder (1982a). ALECSO is considering supporting a number of marine research and conservation projects including the completion and management of the aquarium at Port Sudan, a feasibility study of Sanganeb Marine National Park and the establishment of the Gebel Elba Conservation Area in collaboration with the Egyptian Academy of Scientific Research and Technology (Nasr, 1985). There are plans for permanent moorings at some of the popular recreational diving sites (Schroeder *et al.*, 1980b), including Shaab Rumi which would also provide an ideal site for underwater research (Vine and Vine, 1980).

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## GEBEL ELBA CONSERVATION AREA

**Geographical Location** Southern Red Sea coast, including the island groups of Siyal off Adal Deib and Rawabel off Abu Naam, north to Shalatein, south to 22°N, and west to 36°E. The area is 290 km from Port Sudan and 520 km from Quseir, the nearest Egyptian town.

**Area, Depth, Altitude** About 4800 sq. km.

**Land Tenure** The Conservation Area lies in the Sudan Government Administration Area (SGAA), which may be considered Sudanese territory or Egyptian territory under partial administration by the Sudanese Government.

**Physical Features** Gebel Elba and other mountains in this area drain eastwards to the Red Sea through gently sloping plains. The area is remarkable for the unusual amounts of rain that it receives, mainly in winter. The terrestrial part of the Conservation Area is described in Goodman (1985). There is little information on the coastal and marine environment. There are a number of offshore islands forming the Siyal and Rawabel groups.

**Reef Structure and Corals** There are extensive fringing reefs along much of the coast.

**Noteworthy Fauna and Flora** The offshore islands are important for seabirds and turtles. Hawksbill, Green and Leatherback (*Eretmochelys imbricata, Chelonia mydas* and *Dermochelys coriacea*) Turtles nest on Gezira Siyal Kebir. Dugong *Dugong dugon* may occur. Patches of mangrove are found south of Shalatein. Details of the terrestrial fauna and flora are given in Goodman (1985).

**Scientific Importance and Research** A preliminary survey of the terrestrial part of the Conservation Area has been carried out (Goodman, 1985) but there has been no work on the marine environment.

**Economic Value and Social Benefits** There are a number of Bedouin tribes in the area, the most important being the Bischarin. Many of the latter have recently moved to coastal settlements under an Egyptian government programme. A small but apparently prosperous artisanal fishery exists (Goodman, 1985).

**Disturbance or Deficiencies** There was no evidence of significant oil pollution along the coast in 1983 and the fishing industry has little impact (Goodman, 1985). Threats to the terrestrial part are described in Goodman (1985). There is concern that the new coastal road could have a deleterious impact through accelerated development of the area.

**Legal Protection** Under Egyptian law, Decree 701 calls for establishment of the Gebel Elba region as a protected area. In 1984, Sudan agreed to cooperate and it was established under Prime Ministerial Decree No. 450 on 22.4.1986. The protected area includes the offshore islands and coastal mangrove stands, and the Abraq, El Deib and Gebel Elba areas.

**Management** The Decree setting up the park mandates that a branch of the Egyptian Environmental Affairs Division be established for implementing the articles of the decree. It is proposed that the administrative centre should be at Abu Ramad and draft regulations are given in Goodman (1985).

**Recommendations** Goodman (1985) recommends that priority should be given to managing Gebel Elba, the coastal mangroves between Shalatein and Halaib, and the Siyal and Rawabel island groups. The Conservation Area should be developed using a variety of management strategies, one of the objectives being to allow the Bischarin to continue their traditional life style. A more detailed survey is required, particularly of the coastal and marine environments, offshore islands and key species such as turtle, Dugong and birds. ALECSO is considering supporting further work in this area (Nasr, 1985).

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## MUKKAWAR ISLAND AND DUNGANAB BAY

**Geographical Location** 160 km north of Port Sudan; includes the Taila Islands and the mainland opposite, with Mersa Infeikal; 20°50'N, 37°17'E.

**Area, Depth, Altitude** Dunganab Bay is about 300 sq. km in area.

**Physical Features** Crossland (1907, 1911, 1913 and 1919), Moore (1985) and Reed (1964b) describe the physical features of Dunganab Bay. It is a shallow semi-enclosed bay formed by emergent coral reefs. There is a semi-diurnal tide of only a few cm. The prevailing wind throughout the year is north-north-east. Salinity is 42-42.7 ppt. Temperatures drop very rapidly from a maximum of 31.4°C in October to a minimum of 22°C in winter, and there is an annual range of 9.4°C. Further hydrological details are given in Nasr (1982) and Moore (1985).

**Reef Structure and Corals** There are well-formed reefs along the east coast of Mukkawar but no details are available. Vine and Vine (1980) described a number of transects in Dunganab Bay, where corals were not generally well developed and the genus *Galaxea* predominated. Hard corals were rarely found at depths greater than 2 m. Below this, the substrate of fossil coral rock was largely bare, the dominant epifauna being sponges. A reef slope near Ras Abu Hunter on the east side of the bay had only *Galaxea* colonies. Flat-topped knolls of *Porites* were abundant on the south-east side of the Bay. There was a shallow, submerged, poorly developed patch reef 1 km east of Dunganab village. The seaward-facing slope of the reef, north-east of Mesharifa Island within the barrier reef, had a steep *Porites*dominated shallow fore-reef which levelled out at about 10 m with large knolls rising to 5-6 m below the surface, followed by a gradual slope into deeper water. Coral growth was poor in Mesharifa Channel, close to the east end of the island. Approximately 100 m south-east of Mesharifa Island there was a massive knoll of *Galaxea*, 5.5 m high and 8 m in diameter.

At Shambaya Island (150 m x 30 m) on the barrier reef, there was a broad shallow lagoon on the seaward, exposed side, extending about 250 m from a sandspit to the reef-crest. The platform and crest were very turbulent areas and the shallow reef face was deeply incut to form grooves and spurs. *Stylophora* and *Seriatopora* were abundant in the back-reef zone, and *Tubipora musica* was very common on shallow coral heads behind the reef-top. Coral growth was greater on the spurs. On the terrace at 15 m depth, there were rich coral communities including many large *Acropora* tables. At 30 m depth, the slope steepened and was dominated by *Xenia*. The slope from 43 to 50 m depth was notable for the presence of large upright bushy black corals (Vine and Vine, 1980).

**Noteworthy Fauna and Flora** The surrounding waters are well known for Whale Sharks *Rhincodon typus* and the Mesharifa Channel may be a traditional mating ground for manta rays *Manta* spp. Vine and Vine (1980) found that reef fish were rare within the bay, the dominant species being *Gonochaetodon larvatus*, but were abundant on the reef of Mesharifa Island. There are seabird colonies on the Taila Islands and southern end of Mukkawar. Cooper *et al.* (1984) list five species, including the Sooty Gull *Larus hemprichii*, White-eyed Gull *L. leucophthalmus* and three species of terns *Sterna* spp. Further details are given in Moore and Balzarotti (1983). Ospreys *Pandion haliaetus* nest on a small island within Dunganab Bay. There are mangroves on the south end of Mukkawar and at Mersa Infeikal. Turtles have been seen at Shambaya Island and nest on Mukkawar (Vine and Vine, 1980).

**Scientific Importance and Research** Dunganab Bay is considered a unique marine biotope within the Sudanese Red Sea on account of several unusual features, including the paucity of reef corals and butterfly fish, the presence of *Acanthaster planci* feeding on *Xenia*, and the presence of large knolls of *Galaxea* (Vine and Vine, 1980). The paucity of hard corals in the Bay could be due to the greater sedimentation, turbidity and extremes of temperature associated with enclosed waters. However, on the fringes of mersas, where similar conditions prevail, prolific coral growth extends shorewards until banks give way to sand. Furthermore rich coral growth is found on the reefs fringing the north basin of Dunganab Bay where conditions are even more extreme. Poor coral growth may be largely due to high densities of *Acanthaster planci* (see below) (Moore, 1985).

**Economic Value and Social Benefits** Dunganab Bay was once an important pearl oyster fishing centre (Ormond, 1978). *Pinctada margaritifera* was cultivated as early as 1905 but mass mortalities caused a serious decline in production in the 1960s (Reed, 1964b). The Fisheries Research Center of the Agricultural Research Corporation is now carrying out a research project on cultivation of this species in this area (George *et al.*, 1984; Nasr, 1979, 1982 and 1985; Schroeder, 1982a).

**Disturbance or Deficiencies** *Acanthaster planci* is relatively conspicuous and feeds on the soft coral *Xenia* in Dunganab Bay. Population densities are significantly higher than elsewhere along the coast, and probably contribute to the paucity of reefs through excessive predation pressure on growing corals. A decline of *A. planci* from 1972 to 1978 may have been due to exhaustion of coral colonies. The recovery of the *A. planci* population from 1978 to 1982 followed closely the re-establishment of small colonies of hard corals (Moore, 1985). There have been mass mortalities of cultivated *P. margaritifera* within the semi-enclosed bay close to Dunganab village (Vine and Vine, 1980; Nasr, 1982).

**Legal Protection** None.

**Management** None.

**Recommendations** The area of Mukkawar Island and a section of the coast would constitute a valuable National Park or Biosphere Reserve (Ormond, 1980a). The island could be established as a refuge for terrestrial wildlife.

## PORT SUDAN PROPOSED MARINE NATIONAL PARK AND PROPOSED ABU HASHISH MARINE RECREATION CENTRE

**Geographical Location** Proposed Marine National Park to include the fringing reefs and beaches within and to the north and south of Port Sudan; 19°38'N, 37°07'E.

**Physical Features** A 4 km long mersa forms a natural harbour with a depth of several tens of metres. There is a certain amount of coral growth in the harbour mouth, where some of the reefs face south and are fairly protected. During northerly winds, a strong down current of lagoonal water in the grooves carries rich oxygen-saturated water from the shallows to deep water (Vine and Vine, 1980). Outside the harbour mouth there are fringing reefs to north and south which are exposed to the prevailing north-west winds (Schroeder, 1978, 1982a and b). Sea surface temperatures off Port Sudan range from 26.2 to 30.5°C, although in shallow and/or enclosed waters they may be higher (Schroeder, 1982a and b).

**Reef Structure and Corals** The fringing reefs to the north and south of Port Sudan are about 1 km wide and have seagrass, algae and coral cover, with a spectacular sloping fore-reef dropping several tens of metres. Vine and Vine (1980) studied the reef 1 km north of the promontory at the northern point of the harbour entrance, where coral growth is accelerated by an abundant food supply in the long-shore current. Corals were found to 80 m depth but there was a paucity of marine life, including fish, below 30 m.

The reef changes direction at the promontory and is more exposed to prevailing winds to the north and less exposed between it and the harbour entrance. The more exposed northern section had a more prolific growth of hermatypic corals and a less acute reef face. The reef crest was deeply incut and dominated by *Pocillopora* and *Porites*. There was a zone of *Galaxea* at about 2 m depth. The shallow reef-edge formed a steep spur and groove system, sometimes undercut, with numerous corals on the spurs, and the grooves dominated by the encrusting alga *Porolithon*. The terrace at 8-9 m depth was rubble strewn with large but dead tables of *Acropora*. *Balanophyllia* and *Pocillopora* were common on a small pinnacle which rises from 10 m to 6.5 m depth. A deeper reef face descended to 26 m with sparsely distributed large *Acropora* tables and other corals; *Xenia* and various sponges predominated. There was a narrow shelf at 26-27 m depth below which a gradually steepening reef face extends to a sandy terrace with isolated rocky outcrops at 46 m depth.

To the south of the promontory, the reef face had an almost vertical drop-off from the crest to about 35 m depth with a rich growth of gorgonians, soft coral *Dendronephthya* and at greater depths, antipatharians. There were numerous deep crevices in the crest which was undercut at 3 m where sediment collects. The reef top was dominated by *Pocillopora* sp., bushy *Acropora* and *Platygyra*. A spur and groove system extended from the crest to the base of the reef at 35 m depth. At 5 m depth there was a large colony of *Galaxea*, brackets of *Acropora corymbosa*, several faviids and the alcyonacean *Dendronephthya savigna*. At 8 m depth, *Millepora dichotoma*, *Echinopora*, *Porites* and *Fungia* were found on the steep reef face. At 10 m depth, the reef face was very steep and undercut, typically with *Gorgonella flexuosa* and *Dendronephthya*. Below 10 m coral cover was poor, mainly *Porites* and *Acropora corymbosa*, with large tables of *A. pharaonis* at 15 m depth (Vine and Vine, 1980).

The fringing reef to the north of Port Sudan has been described by Aboul-Basher (1980), Mergner (1971) and Schroeder and Nasr (1983). A total of 59 genera and subgenera of stony corals have been recorded from this area (Schroeder, 1982a).

**Noteworthy Fauna and Flora** On the northern fringing reef, at certain times of the year, such as January, strong down currents of lagoonal water carry plankton towards the deep reef and as a result large numbers of usually shallow water fish are found as deep as 35 m. Reef fish which are not normally plankton feeders, such as parrotfish (Sparidae), are seen to shoal away from the reef and feed on plankton, particularly pteropods. Vine and Vine (1980) recorded about 60 species of fish on this reef; fish on the outer reefs were also described. A total of 282 species of molluscs has been found on reefs around Port Sudan and Suakin (Mastaller, 1978).

**Scientific Importance and Research** A detailed survey was carried out by Vine and Vine (1980). The Institute of Oceanography has started some monitoring and surveying work including mapping and describing the fringing reef (Schroeder *et al.*, 1980b; Schroeder and Nasr, 1983), monitoring pollution (Nasr *et al.*, in press a and b) and collecting oceanographic data (Nasr *in litt.*, 1.2.87).

**Economic Value and Social Benefits** The sea is the major source of recreation for the people of Port Sudan. Glass-bottom boat trips were a major attraction until the "coral gardens" at the harbour entrance became impoverished. The Red Sea Hotel caters for SCUBA divers (Schroeder, 1978 and 1982a). The wreck of the *Umbria* is a popular diving site (Schroeder, 1981a). The Port Sudan Public Aquarium was started in the 1970s but had to be abandoned. It was resubmitted as a project to ALECSO and it is hoped that it will now be completed in 1987 (Nasr, 1985).

**Disturbance or Deficiencies** Increasing industrialization and pollution are major disturbances. The main forms of pollution are hot water effluent from an electrical power station, oil, chemicals, ships' waste and a variety of other products ranging from flour to asphalt. The harbour has been modernised and extended to cope with increasing shipping activity (Schroeder, 1982a). The coral gardens at the port entrance are considered to be completely ruined (Schroeder, 1981b).

**Legal Protection** None.

**Management** Regulations prohibiting collection and trade in shells and corals are well enforced (Schroeder 1982a). Signboards have been installed and leaflets have been produced in five languages for distribution to ships' crews and tourists. Schools are visited, lectures given and the media has been used to increase public awareness. Fishermen now report coral poachers and oil disposal by foreign ships outside Port Sudan harbour. The Port Police have a vessel that patrols the area, assisting with enforcement (Nasr, 1985).

**Recommendations** A preliminary proposal for a Marine Park to include the reef area in the immediate vicinity of Port Sudan has been made. It was suggested that work on this park should run concurrently with the establishment of the Sanganeb Marine National Park (Ormond, 1980a; Schroeder, 1981d and 1982a). The *Umbria* has been recommended as a protected diving site (Schroeder, 1982a) and a proposal has been drawn up (Schroeder, 1981a).

Just to the north of the port, a recreation centre has been proposed at Abu Hashish Reef. Although this was a heavily polluted area, it was intended to re-establish circulation of water around a series of fringing reefs to clean it up (Schroeder, 1981b and 1982a) and use it as an alternative site to the Coral Gardens for glass-bottom boats. A report (Nasr and Pichon, 1986) has been submitted to the harbour authorities and National Council for Research, and the area is to be developed in the near future (Nasr, 1985).

## SANGANEB PROPOSED MARINE NATIONAL PARK

**Geographical Location** Red Sea, 25-30 km north-east of Port Sudan; 19°45'N, 37°25'E.

**Area, Depth, Altitude** The Park would cover approximately 10 sq. km (100 ha); the reef and lagoon are 6 km (N-S) and 2 km (E-W).

**Land Tenure** State property.

**Physical Features** Sanganeb Atoll rises from a steep sea-floor of more than 800 m depth and is characterized by steep slopes on all sides with terraces in their upper parts and occasional spurs and pillars. The rim of the atoll reaches the surface on all but the western side where it is submerged. The outer rim encloses three lagoons: a large one in the north with 51 m maximum depth and a wide opening to the west; a small one with 27 m maximum depth bordered to the north by a series of patch reefs; and a medium-sized southern one with 9 m maximum depth, which is completely enclosed, except for a narrow channel leading north, and which provides a safe anchorage for small boats (Schroeder, 1979). The water is extremely clear and visibility of up to 46 m has been recorded (Schroeder *et al.*, 1980b).

**Reef Structure and Corals** The atoll has a highly diverse coral fauna and is characterized by 13 different bio-physiographic reef zones, each providing typical coral reef assemblages (Anon., 1981). Coral communities have been described by Mergner and Schuhmacher (1985) and Schuhmacher and Mergner (1985). A total of 86 coral species in 35 genera has been recorded.

**Noteworthy Fauna and Flora** The fish fauna is diverse and includes large groupers and wrasse e.g. Napoleon Wrasse, Barracuda, Hammerhead, (*Cheilinus undulatus*, *Sphyrnaena spp.*, *Sphyrna* spp.) and occasionally Tiger Shark *Galeocerdo cuvieri* and White-tip Sharks *Triaenodan obesus* (Anon., 1982). *Genicanthus melanospilus* (Pomacanthidae) which has a patchy distribution in the Red Sea occurs on the deep water reefs (Ormond, 1980b).

**Scientific Importance and Research** The Institute of Oceanography, which was given a large part of the buildings on the atoll for a research station in 1978, has undertaken studies of the three lagoons. Aerial photography at the scale of 1:7500 has been carried out; a tidal station is to be installed; the Meteorology Department is interested in establishing a weather station, and the Survey Department will participate in hydrographic work (Schroeder, 1979). In 1980 a quantitative analysis of coral communities was carried out (Mergner and Schuhmacher, 1985a; Schuhmacher and Mergner, 1985). Sanganeb is one of the few atolls in the Red Sea and is considered to have optimal conditions for coral growth (Scheer, 1984).

**Economic Value and Social Benefits** European divers frequently visit the atoll on organized tours, particularly from October to May. The atoll was also popular with Sudanese people when boat trips were regularly available. Regular tug boat trips have been discontinued and local access is therefore restricted (Schroeder, 1979), although local people still make use of the lighthouse twice-monthly service for day trips. Currently about 500-700 people a year visit the atoll (Anon, 1981 and 1982).

**Disturbance or Deficiencies** The atoll is reported to be largely unaffected by pollution or depletion by collecting, although there have been some reports of coral and shell collecting, anchor damage and other disturbances caused by large numbers of boats and divers. Spearfishing has been reported as heavy (Kundaeli, 1978; Schroeder, 1979) but may not be too serious now (Anon., 1982).

**Legal Protection** Sanganeb was declared a closed area for commercial fishing by the Commissioner of the Red Sea Province in April 1978. The Marine Fisheries Regulations of 1937 and 1975, prohibiting coral and shell collecting and the use of spearguns, are in force. However, the atoll has no official protection as a reserve.

**Management** Administered by the Commissioner of the Red Sea Province. The lighthouse properties are administered and staffed by the Sea Ports Corporation (SPC), Port Sudan. Access to the island is free, although arrangements must be made with the Tourist Corporation Office, Port Sudan, for overnight stay. The 1978 orders issued by the Red Sea Commissioner are enforced by local police and followed up by the Sudanese Marine Conservation Committee (SMCC). Signboards have been installed by the SMCC.

**Recommendations** The position of Sanganeb in the open sea, making it comparatively safe from coastal, industrial and port pollution, makes it particularly suitable for reserve status and the proposed Marine National Park would be a focal point for tourist activity (Schroeder, 1979). There is an urgent need for some form of control of tourists as, with the introduction of an automatic light signal, there are no permanent inhabitants on the islands. SMCC is already involved in working with government departments towards the establishment of the park and a plan has been drawn up (Davis, 1982), the first phase of which was sponsored by IUCN/WWF. $10 000 has been provided for a new glass-bottom boat engine and the visit of an expert, although the first phase was not completed. ALECSO is considering supporting the second stage of the feasibility study (Nasr, 1985). It may be practical to include the barrier reef, from Le Mercier Shoals north to about Shaab Rumi, and the Shaab Rumi Atoll itself, in the park (Schroeder, 1979; Anon., 1982). It has also been recommended that the proposed Marine National Park should include the fringing reefs beginning at Mersa Waiai and extend towards the north to include the Mersa Darur reef. The area has been proposed as a Biosphere Reserve and was nominated as a World Heritage Site in 1981 (Anon., 1981) but has not yet been accepted.

## SUAKIN ARCHIPELAGO PROPOSED NATIONAL PARK OR RESERVE

**Geographical Location** the proposed protected area would comprise seven islands lying in the south-east of the Suakin Archipelago on the southern part of the Sudanese coast, about 27 km from Suakin. THe islands of Talla Talla Kebir, Saghir, Masamirit, Barra Muss Saghir and Seil Ada Kebir lie to the north; 19°14'N, 37°50'E.

**Area, Depth, Altitude** The Archipelago is approximately 100 km long with maximum depth of c. 300 m. The islands are low lying.

**Physical Features** The coastal shelf widens to over 100 km in the region of the Suakin Archipelago. The "Seven Islets", which would lie within the proposed park, are in fact a group of eight islets in the south of the Archipelago. Wave action is severe at some islets in the Archipelago, such as Barra Muss Saghir, which is characterized by huge eroded channels, no coral and large rounded boulders (Moore and Balzarotti, 1976). There is good visibility. Seil Ada Kebir, (285 m x 162 m), is low lying (5 m) and has a sandy beach, 1.8 km long and 10-32 m wide (Hirth and Latif, 1980). It is covered with grasses and shrubs and surrounded by a lagoon which is widest on the northern side (Latif, 1980). Talla Talla Kebir and Saghir are on the edge of the shallow coastal shelf (Moore and Balzarotti, 1976).

**Reef Structure and Corals** In general the reefs slope from a crest for a few metres before dropping vertically to over 300 m depth, broken by small ledges, the first one occurring at about 45 m. Off the larger islands, greater areas of coral occur at 6-18 m depth before the vertical drop-off. Coral at the two large islands, Talla Talla Kebir and Saghir, is more diverse and abundant, due to the shallow shelf, than it is on the offshore islets where the sea bottom is steeper. Most corals are prevented from growing below 13 m, presumably by turbidity arising from the muddy coastal shelf. Antipatharians, gorgonians, sponges and encrusting organisms, including large stands of black coral occur on steep walls. Massive *Porites* spp, large brain corals (such as *Platygyra), Acropora* sp. and *Pocillopora* are found on gentler sloping faces. Soft corals, particularly *Sarcophyton* sp., are common. Calcareous and filamentous algae are found in shallow water near the reef crest. Black coral, Antipatharia, is abundant (Moore and Balzarotti, 1976).

**Noteworthy Fauna and Flora** Fish are abundant and very diverse, particularly predatory species, such as Black-tip *Carcharinus melanopterus* and

White-tip *Triaenodan obesus* Reef Sharks and larger pelagic sharks such as Barracuda *Sphyraena* spp. Jacks *Caranx* sp., Rainbow Runner *Elegatis bipinnulatus*, surgeonfish Acanthuridae, wrasse Labridae, butterfly fish Chaetodontidae, parrotfish Scaridae and the boxfish *Ostracion tuberculatum* (Ostracionidae) are particularly common. In the northern islands round Masamirit, demersal predatory fish are rare and so large shoals of *Anthias squamipinnis* are seen. *O. tuberculatum* is less common here. The greatest diversity of fish is seen at Talla Talla Kebir and Saghir. The herbivorous *Acanthurus sohal* occurs in abundance (Moore and Balzarotti, 1976).

Four species of turtle have been reported by fishermen and there is a large colony of Hawksbills *Eretmochelys imbricata* on Seil Ada Kebir (Groombridge, 1982; Hirth and Latif, 1980; Latif, 1980). The Sooty Gull *Larus hemprichii*, Brown Noddy *Anous stolidus* and four species of tern *Sterna* spp. nest in the area (Gallagher *et al.*, 1984; Ormond, 1980a).

**Economic Value and Social Benefits** The archipelago is an important fishing ground and also a spectacular diving site with great tourist potential (Ormond, 1980a).

**Disturbance or Deficiencies** There is minimal disturbance to the reefs. Litter and small tar balls have been found on Seil Ada Kebir. Yemeni fishermen may visit the Suakin Archipelago and capture turtles but otherwise there is little interference (Frazier, 1981). Exploitation of Hawksbills on Seil Adda Kebir is negligible but is a potential threat particularly if tourism develops rapidly (Hirth and Latif, 1980; Latif, 1980). Gas, mainly methane, has been found in two wells in the Archipelago in commercial quantities, but has not yet been exploited (Schroeder, 1982a). If it is, this could pose a threat to the reefs.

**Legal Protection** None.

**Management** There is little enforcement of the national legislation to control collection of turtles, shells and corals.

**Recommendations** Ormond (1980b) recommends the creation of a National Park or Biosphere Reserve. Since most of the important biological sites are scattered and the area is also an important fishing ground, a suitable zoning scheme and management plan will have to be developed in cooperation with the fisheries authorities. A smaller reserve to include Eitwid and Green Reefs and two islets has also been recommended (Ormond, 1976). These recommendations are being considered by the SMCC (Nasr *in litt.*, 1.2.87).

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## SUAKIN HARBOUR

**Geographical Location** 19°08'N, 37°17'E.

**Physical Features** A long narrow channel, 12-45 m wide, with fringing reefs, extends about 2 naut. mi. (3.7 km) from Suakin Island to the outer beacons. There are two shallow inner basins, one surrounding Suakin Island and the other forming a narrow inlet on the north side of Quarantine Island. There is reasonable water exchange due to wind-driven currents. The water is somewhat turbid due to fine silt on the harbour bottom (Vine and Vine, 1980).

**Reef Structure and Corals** Fairly rich coral communities occur with species characteristic of open water reefs, although corals are restricted to shallow zones due to the silty conditions on the bottom. Just outside the harbour the fringing reef is particularly rich with a dense live coral cover. Vine and Vine (1980) studied a reef on the southern side of the harbour channel which is within the protection of the channel but still receives strong buffeting during storms. Fauna on the gently sloping reef terrace was sparse, the richest area for coral growth being from 1 to 3 m depth where *Pocillopora*, *Stylophora* and *Porites* predominated. Below 4 m, corals were sparse but several encrusting species were present on the upper section of the main slope and there were isolated outcrops of *Pocillopora* down to 10 m. The slope leveled into a terrace at about 11 m depth below which there was a sloping section to 15 m, followed by a sharply undercut cliff-face dropping to a silty bottom at 19 m depth. The cliff face had numerous *Juncella* (whip gorgonians) and some sediment tolerant corals.

**Noteworthy Fauna and Flora** Dafalla and Karim (1980) describe seaweed zonation along a stretch of coast in Suakin Harbour opposite the Marine Biological Station. Vine and Vine (1980) recorded fish in the harbour and found abundant fish life on the outside fringing reef. Large *Plectorhyncus harawi* (Lutjanidae) and *Epinephelus tauvina* (Serranidae) were common. Many small sharks were seen, including White-tip *Trianedon obesus* and Black-tip *Carcharinus melanopterus* Reef Sharks. Green Turtle, Hawksbill Turtle (*Chelonia mydas, Eretmochelys imbricata*) and a Dugong *Dugong dugon* have been sighted (Vine and Vine, 1980).

**Scientific Importance and Research** The Suakin Marine Laboratory is situated on the southern side of the harbour channel and is studying selected aspects of the reefs as a comparative project for the Institute of Oceanography's monitoring programme on Port Sudan's fringing reef (Nasr *in litt.*, 1.2.87; Schroeder, 1978).

**Economic Value and Social Benefits** No information.

**Disturbance or Deficiencies** The proposed new harbour, to the north of Suakin will increase shipping activities and put additional pressure on the reefs (Kundaeli, 1978). There are also plans to rehabilitate old Port Suakin and provide berths for large tankers as well as facilities for sport fishing (Anon., 1982).

**Legal Protection** None.

**Management** None.

**Recommendations** Not known.

# SULTANATE OF OMAN

## INTRODUCTION

### General Description

The Sultanate of Oman has two physically separate parts. The northern and smaller part is the mountainous Musandam Peninsula which projects into the Strait of Hormuz and has a shoreline of about 300 km facing both the Gulf and the Gulf of Oman. A 65 km length of the United Arab Emirates coast separates it from the much larger southern section (1500 km) facing the Gulf of Oman and the Arabian Sea. This has a mixture of cliffed, low lying dune and sabkha (saline flats) shorelines which continue southwards to the mountainous southern region of Zufar (Dhofar). There are three main groups of islands: Jaza'ir Daymaniyat (Daymaniyat Islands) off the capital coast, Jazirat Masirah (Masirah Island) off central Oman, and the Kuria Muria Islands off Zufar.

The south-west monsoon (mid June-mid September) is the principal factor controlling the community structure of the marine flora and fauna of the southern Arabian Peninsula. It blows parallel to the southern coastline, setting up a north-easterly current from Somalia to Western India. The net effect is to move surface waters off shore which are replaced by cool, clear, nutrient-rich waters typical of upwelling conditions. These have a high productivity and blooms of phyto- and zooplankton. During winter, the monsoon gyre reverses, bringing warm, north-easterly air from the mountains and high desert some way inland. Water quality and temperature return to those more characteristic of tropical oceans (Barratt, 1984; Savidge *et al.*, 1986).

The seasonal pattern is reversed in the Gulf of Oman and eastern Gulf adjacent to the Musandam Peninsula, where sea surface temperatures are relatively low in February and high in May and August, apart from localized upwellings which can drop the temperature. Certain bays, apparently in the lee of the current, are nearly always murky owing to suspended sediment and upwelling, which, as on the Arabian Sea coast, gives rise to algal blooms, mainly in winter. In the Masqat (Muscat) area, surface water temperature varies between at least 17° and 32°C. Clarke *et al.* (in press) summarize information on climate and geology.

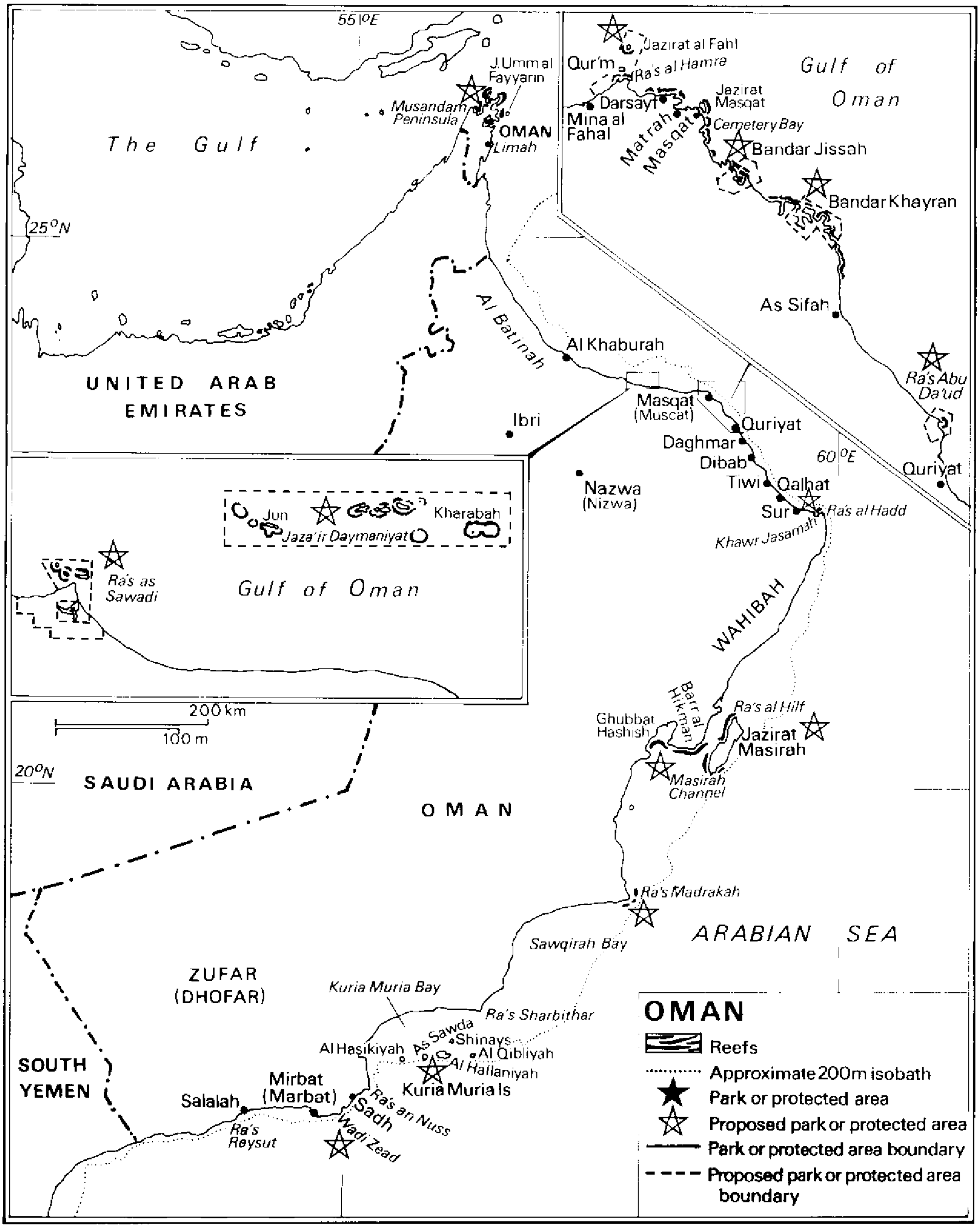
Major coral growth is restricted to four areas: the Musandam Peninsula (the Gulf); the rocky shores, bays and islands in and adjacent to the Masqat area (Gulf of Oman); the straits, shallows and shores west of Jazirat Masirah (Arabian Sea); and some isolated sheltered locations in Zufar and the Kuria Muria Islands (Arabian Sea). Other parts of the coast either lack corals or have limited growth of small, scattered colonies, due mainly to the absence of suitable substrate (e.g. along the sandy Al Batinah coast), or to seasonal upwellings of cold water on the Arabian Sea coast.

Most of the sublittoral zone of Oman is soft substrate, but the very varied nature of the coastal morphology and hydrological regime creates interesting biotic zones. The coast can be divided into a number of distinct areas (Clarke *et al.*, in press). Around the Musandam Peninsula (*see separate account*), there are precipitous slopes that continue below water to produce depths of 40 m close to shore and give a fjord-like appearance, except at the heads of khawrs (saline creeks, coastal lagoons or bays) where stony and gravel beds slope gently downwards. There is little reef development despite the dominance of corals on hard substrate. Further east, the Al Batinah coast is low-lying, mainly sandy with scattered lagoons and inlets, some of which have mangroves. Sublittoral slopes are moderate to very gradual in this area and there is no coral (Anderlini, 1985).

Towards Masqat there is a mixture of sandy beaches, rocky headlands and islets, forming a complex topography, both above and below water. The coast between Qur'm (Qurm) and Bandar Khayran is predominantly rocky with cliffs exceeding 60 m in places. Both true reefs and coral communities are found and have been described by Green (1983) and Salm and Sheppard (1986). Hard corals are largely confined to islands, shoals and the rocky eastern coast. Exposed north and east-facing coasts tend to have relatively small scattered coral colonies and more extensive patches of alcyonarians, chiefly *Sarcophyton*. Coral communities tend to be confined to depths above 12-18 m but certain corals grow on rocky outcrops below 30 m depth (e.g. *Culicia, Balanophyllia, Polycyathus* and *Leptoseris*). The maximum depth of coral growth is determined by the appearance of soft substrate below 15-20 m depth and the usual presence of a thermocline at 12-15 m depth, below which the water is both turbid and cold (Salm and Sheppard, 1986).

Most corals grow directly on bedrock or dead parts of other coral colonies to form a shallow veneer over the underlying substrate. However, conditions have favoured the build-up of small true reefs in places. These incipient patch and fringing reefs are generally restricted to sheltered coasts, such as bays and coves and along the south coasts of islands. Exceptions are found at Jazirat Kharabah (Kharabah Island) and Darsayt where the gradient of the seabed is gradual and suitable substrate is found between 8 and 12 m depth (Salm and Sheppard, 1986). The reef crests are subtidal (c. 1 m below the extreme low tidal datum). Small frame reefs, rarely exceeding 5 m in thickness, and monogeneric coral communities are found in water depths of 5-15 m. Although large *Porites* and *Acropora* colonies can be found (Green, 1983), corals of these species are generally less than 2 m in diameter, with some localized but notable exceptions in the case of *Porites*. The main types of reef occurring in the Masqat area are as follows (Salm and Sheppard, 1986):

1. Incipient patch or fringing reefs dominated by *Porites* (e.g. Jaza'ir Daymaniyat, Cemetery Bay, coves between Yiti and As Sifah, Bandar Khayran, Ra's Abu Da'ud) with a few small scattered colonies of other corals. *Porites* is an important reef builder, forming planed platforms in shallows which may be covered by other species, and extending seawards to a border of colonies attaining 2-4 m in diameter. These large *Porites* colonies and *Porites*dominated reefs probably form the oldest continuously living reefs in the Masqat area (Salm and Sheppard, 1986).


55°E
25°N
20°N
60°E
The Gulf
UNITED ARAB EMIRATES
SAUDI ARABIA
OMAN
SOUTH YEMEN
ZUFAR (DHOFAR)
J.Umm al Fayyarin
Musandam Peninsula
OMAN
Limah
Al Batinah
Al Khaburah
Ibri
Masqat (Muscat)
Quriyat
Daghmar
Dibab
Tiwi
Qalhat
Sur
Ra's al Hadd
Khawr Jasamah
Nazwa (Nizwa)
WAHIBAH
Barr al Hikman
Ghubbat Hashish
Ra's al Hilf
Jazirat Masirah
Masirah Channel
Ra's Madrakah
ARABIAN SEA
Sawqirah Bay
Kuria Muria Bay
Ra's Sharbithar
Al Hasikiyah
As Sawda
Shinays
Al Qibliyah
Al Hallaniyah
Kuria Muria Is
Mirbat (Marbat)
Salalah
Ra's Reysut
Sadh
Ra's an Nuss
Wadi Zead
200 km
100 m
Jazirat al Fahl
Qur'm
Ra's al Hamra
Gulf of Oman
Jazirat Masqat
Darsayt
Mina al Fahal
Matrah
Masqat
Cemetery Bay
Bandar Jissah
Bandar Khayran
As Sifah
Ra's Abu Da'ud
Quriyat
Jun
Jaza'ir Daymaniyat
Kharabah
Ra's as Sawadi
Gulf of Oman
OMAN
Reefs
Approximate 200m isobath
Park or protected area
Proposed park or protected area
Park or protected area boundary
Proposed park or protected area boundary

2. Incipient patch reefs dominated by *Pocillopora damicornis* (e.g. Jaza'ir Daymaniyat, Jazirat al Fahl (Fahal Island) and Jazirat Masqat (Masqat Island), Cemetery Bay, Bandar Jissah, Bandah Khayran and Ra's Abu Da'ud) with few small scattered colonies of other corals particularly around the periphery. Pocilloporid reefs are present in relatively sheltered environments, have high live coral cover (80-100%) and are essentially monospecific in composition with maximum framework thickness of 2-4 m (although 6-8 m has also been recorded).

3. Incipient fringing reefs dominated by tabular and ramose *Acropora* spp. (e.g. Bandar Khayran). Acroporid reefs were once extensive (Glynn, 1983) but many have been killed and are being recolonized (*see* 6).

4. Mixed coral assemblages:

   - on incipient fringing reefs structurally dominated by *Porites* (e.g. Bandar Khayran).
   - on incipient fringing reefs with a largely obscured underlying framework showing patchy distribution of corals (e.g. Bandar Khayran).
   - forming anything from a 10% to an almost complete cover of underlying baserock (e.g. Ra's as Sawadi (Ra's Suwadi), Daymaniyat and Al Fahl islands, mainland rocky coast and associated islets).

5. Talus banks formed of dead branching coral, (a) with little or no recolonization (e.g. Jaza'ir Daymaniyat, Bandar Jissah), (b) in the process of recolonization by the same species (e.g. Daymaniyat and Masqat islands) and (c) in the process of colonization by different species (e.g. Bandar Jissah).

6. Soft coral covering rock or dead coral colonies.

In addition, areas of rocky or sandy substrate may be covered by small discrete patches (less than 500 sq. m) of *Galaxea* (e.g. Jaza'ir Daymaniyat) or *Montipora* (e.g. Jaza'ir Daymaniyat, Bandar Khayran).

The reefs at Bandar Jissah, Jaza'ir Daymaniyat, Qur'm-Al Fahl, Ra's as Sawadi and Bandar Khayran are described in separate accounts. The most important sites for coral growth are considered to be two coral assemblages at Bandar Khayran, the deep communities off Jazirat al Fahl and the rocky shelf communities between Al Fahl and the adjacent mainland peninsula (Salm and Sheppard, 1986). At Cemetery Bay there is a *Porites* reef with huge individual colonies 3-5 m in diameter, which are perhaps 300 years old. At Ra's Abu Da'ud, in the eastern part of the Capital Area, corals are abundant and relatively diverse (*see separate account*). Further east, the reefs just to the north of Ra's Qalhat, between Quriyat and Sur, are composed of *Porites* sp. heads, 3 m in diameter, with small clumps of *Pocillopora* sp. attached to their upper surfaces. Further east still, there are several parallel reefs about 50-60 m off shore in 5-10 m depth which are unusual in being composed almost entirely of soft corals, predominantly *Sarcophyton* sp., with some *Heliopora* sp. These are in good condition and include the hard coral genera *Stylophora, Acropora, Goniopora, Pocillopora, Favites, Platygyra* and *Porites* (Clarke *et al.*, in press).

Eastwards to Ra's al Hadd, mountains lie close to the shore and cliffs and rocky headlands descend vertically in many areas, notably between Daghmar and Dibab, and around Tiwi. In the former case, steep, rocky substrate continues to about 20 m depth before giving way to sand, and hard substrate is encountered again at a depth of about 30 m several hundred metres off shore. Further east, cliffs do not descend as steeply or as deeply below water, but flatten out at an incline of less than 10° to at least 15 m deep. Even where there is hard substrate there is little coral and there are no reefs. In some areas, soft corals predominate and only scattered colonies of *Stylophora, Pocillopora, Acropora* and *Platygyra* are present. Water visibility may be poor at certain times of year (3-5 m) due to algal blooms (Glynn, 1983). Near Ra's al Hadd, the coastal strip becomes low-lying and wide, with sandy beaches continuing smoothly into a sandy sublittoral zone. Large inlets occur, some being muddy depressions set in sabkha and supporting mangroves, while others have sandy or rocky sublittoral and intertidal habitat. Only one of these, Khawr Jaramah, has notable coral communities which have recently been discovered and are yet to be studied and described (Salm *in litt.*, 16.12.86).

South of Ra's al Hadd, the coastal topography along the Arabian Sea, is one of rocky cliffs and headlands broken by sandy beaches (Anderlini, 1985; Sheppard, 1986a). The cliffs or rocky headlands terminate at the low tide level or just below, from where coarse sand continues; wave energy may be very high here causing severe scour. Sandy beach leading to a sandy sublittoral is the dominant habitat south from the Wahibah Sands to the northern edge of the Barr al Hikman Peninsula. Beyond this, both the sublittoral habitat and the degree of exposure of the coast changes, and the fine offshore sediments grade into mud in the shelter of Jazirat Masirah and the bay of Ghubbat Hashish. Most of the coastline around the peninsula is sandy with tidal inlets (Clarke *et al.*, in press). Reefs have recently been discovered fringing much of the south-east and south-west coasts of Barr al Hikman and appear to be much more extensive than any of the Capital Area fringing reefs. They are structurally quite different from other Oman reefs, being formed of huge *Platygyra* colonies with basins 100% covered by whorls of *Montipora foliosa* (Salm *in litt.*, 16.12.86). The slope is almost horizontal opposite Jazirat Masirah, where a huge, low energy environment supports enormous populations of seabirds and the only significant seagrass beds in Oman. Ra's Madrakah, further south on the mainland is mainly rocky, with abundant algae, spiny lobster *Panulirus homarus*, a range of corals and abundant fish (Clarke *et al.*, in press).

The Zufar coast faces predominantly south-east, but rocky bays are aligned in a variety of directions giving a range of different exposure regimes. The summer upwelling causes the development of substantial seasonal algal beds, including a conspicuous species endemic to the Arabian Sea *Sargassopsis zanardinii* (Nizamuddin *et al.*, 1986) and a kelp species *Ecklonia radiata* whose distribution until now was restricted to the southern hemisphere (Barratt, 1984; Barratt *et al.*, 1986a). Sea surface temperatures are cold (16-18°C), nutrients are high and water visibility generally good (20 m) at this time of year (Barratt, 1984; Savidge *et al.*, 1986). The Salalah area is mainly sandy beach and sublittoral, although rocky outcrops occur and become more frequent towards Mughsayl. Reef building corals are present in small, isolated colonies, often extensively shaded by *Sargassum* or *Sargassopsis* during late summer and autumn. *Pocillopora* and *Montipora* are seldom seen, and no incipient reef frame is observed.

Parts of the coast, specifically the Mirbat (Marbat) Peninsula and some locations on the Kuria Muria Islands (*see separate account*) are composed of metamorphic rocks. Only in the Sadh area and in parts of the Kuria Muria do these form a significant rocky substrate down to 30 m depth or more and there are no true reefs. From Mughsayl to the border, precipitous cliffs dominate the immediate shoreline in most places, giving rise to a rocky intertidal zone interspersed with sandy bays, but as is the case in most parts of Oman other than Musandam, the rock extends sublittorally to only 2-4 m depth before meeting sand. Immediately off shore, sand is the dominant habitat, although flat rocky areas are also encountered and corals are found scattered through the macroalgae (Barratt, 1984; Campbell and Barratt, 1983).

Wadi Zead, on the Mirbat coast, is a sheltered bay which is the only locality in this region known to have coral reefs rather than scattered coral colonies (*see separate account*). The macroalgal/coral assemblage characteristic of much of the coastline does not occur abundantly west of Ra's Raysut (Glynn, 1983), although some isolated areas of dense *Sargassopsis* beds occur on the more exposed sublittoral fringes. Algal/coral assemblages are restricted in western Zufar due to lack of suitable substrate.

Eleven marine sites and areas of special interest (SASIs) have been identified by Clarke *et al.* (in press), of which the following include coral reefs: 1. Dawhat ash Shishah, 2. Ghubbat ash Shabus, 3. Khawr Habalayn, 4. Jazirat Habalayn and 5. North Limah Bay (all of which are described in the account for Musandam); 6. Ra's al Hamra (*see account for* Qur'm-Al Fahl); 7. Bandar Khayran (*see separate account*); 8. Ra's Qalhat (*see above*); 9. Ra's Madrakah (*see above*); 10. Wadi Zead Bay (*see separate account*).

Ninety-one coral species in 47 genera, of which 14 species in 11 genera are ahermatypic, have been identified so far in Oman (Salm and Sheppard, 1986; Sheppard, 1985). Earlier lists include Rosen (1971) (15 coral genera from the United Arab Emirate coast (then Trucial Oman) and Sawqirah Bay, off the Jazir coast, south-east Oman), Green (1983) (22 species in Muscat) and Green (1984) (28 species in Oman). The fauna is greatly reduced compared to the Indian Ocean and Red Sea, but is remarkable for waters whose temperature falls to 17°C, at least as far north as the Capital Area. Thirty one species have been found only in the north of the country and do not appear to penetrate into colder southern waters while 15 species have been found only in the southern area of Zufar and the Kuria Muria Islands. The latter are typical Indian Ocean corals but there is no obvious reason why they do not extend further north. There is therefore an apparent fall in coral diversity towards the equator. The most notable absence from the Oman coral fauna is the family Fungiidae; *Millepora, Tubipora* and *Heliopora* are also apparently absent.

Clarke *et al.* (in press) and Salm (1986a) provide summaries of work on the marine fauna and flora of Oman. A list of reef fish recorded in the Capital Area is given in Salm (1986a). Echinoderm diversity in the Gulf of Aden and the Arabian Sea is described by Price (1982) and off the Zufar coast by Barratt (1984). Molluscs have been described by Barratt (1984), Bosch and Bosch (1982) (who describe 371 species), Lawton (1983) and Smythe (1982); there are also numerous publications on individual species and particular areas. Pearl oysters *Pinctada margaritifera* and *P. radiata* are abundant at Ra's as Sawadi, Jaza'ir Daymaniyat, Bandar Khayran and Ra's Abu Da'ud (Salm and Dobbin, 1986). Barratt (1984) lists algae occurring along the Zufar coast.

The Loggerhead *Caretta caretta*, Green Turtle *Chelonia mydas*, Olive Ridley *Lepidochelys olivacea* and Hawksbill *Eretmochelys imbricata* nest in Oman. Jazirat Masirah (*see separate account*) is the most important site and the world's largest Loggerhead rookery and Loggerhead and Green Turtles are known to nest in several areas in the southern region during the monsoon (Barratt *in litt.*, 15.1.87). Ra's al Hadd is one of the top dozen nesting sites in the world for Green Turtles and Jaza'ir Daymaniyat are particularly important for Hawksbills (Clarke *et al.*, in press; Groombridge, 1982; Ross, 1978; Ross and Barwani, 1981; Salm, 1986a). The Leatherback *Dermochelys coriacea* has been reported but does not nest. The Directorate General of Fisheries has a continuous turtle tagging and surveillance programme in the Capital Area (Salm, 1986a). The Dugong *Dugong dugon* has been reported from the coast near Masqat (Thornback and Jenkins, 1982) and fishermen claim to have seen it. However, it is unknown along most of the coast. There are a few mangrove stands at Qur'm, Bandar Khayran and Quriyat in the Capital Area, Khawr al Sur, Khawr Jaramah, Jazirat Mahawt (Mahawt Island), and Liwa, on the mainland opposite Masirah and in Zufar. Seagrass beds are found sparsely in the Capital Area at Bandar Jissah and Ra's as Sawadi (Salm and Dobbin, 1986) and along the Al Batinah coast. Elsewhere they are found in bays and lagoons. The most extensive seagrass beds are found off Barr al Hikman and in the Ghubbat Hashish (Salm *in litt.*, 16.12.86).

The status of breeding seabirds is reviewed by Gallagher and Woodcock (1980) and Gallagher *et al.* (1984) and summarized by Clarke *et al.* (in press) and, for the Capital Area, Salm (1986a). Ten species are listed, including five species of tern *Sterna* spp., all of which nest on Jaza'ir Daymaniyat. The Masirah area and the Kuria Muria group are also important sites, the latter being important for the Masked Booby *Sula dactylatra* and the Socotra Cormorant *Phalacrocorax nigrogularis*. The Bridled Tern *Sterna anaethetus* has large (10 000 pairs) nesting populations on Jazirat Umm al Fayyarin (Musandam), in the Jaza'ir Daymaniyat and the Masirah area.

**Reef Resources**

About 10% of the population in Oman fish, the greatest concentrations of fishermen occurring along the Al Batinah coast and between Masqat and Ra's al Hadd, although there are also large numbers in the Southern Region. Most fishing is carried out within 5 km of land (Clarke *et al.*, in press). In the Capital Area, artisanal fisheries use set gill nets, set wire traps, seasonal beach seines and opportunistic hook and line methods (Salm and Dobbin, 1986). Sheppard (1986b) gives a brief account of the status of the commercial spiny lobster *Panulirus homarus* in the Zufar area, and there is also an important local fishery based on the abalone *Haliotis mariae* around Sadh in the Southern Region. An early description of the Oman fisheries is given by Bertram (1948); more recent information can be found in Donaldson (1978).

The Al Batinah beaches to the west of the Capital Area are popular for recreation. The eastern beaches and islands are less accessible and are used mainly at week ends. Recreational use of the reefs is increasing and SCUBA diving is popular at Jaza'ir Daymaniyat, Bandah Jissah, Bandar Khayran and particularly Jazirat al Fahl. Salm and Dobbin (1986) provide further details on marine based recreation and fisheries.

**Disturbances and Deficiencies**

Reefs formed of *Acropora* and *Pocillopora* are periodically killed off, partly due to predation by *Acanthaster planci*, but probably also from stress following abrupt drops in temperatures (Salm and Sheppard, 1986). *Acanthaster* has been found in the Gulf of Oman, in the Masqat area, at Jaza'ir Daymaniyat, in the vicinity of Sur and in Khawr Habalayn in Musandam, and was present at about 60% of sites visited by Glynn (1983). There are isolated records from the south coast in the Wadi Feshshree area (Barratt *in litt.*, 15.1.87). In the early 1980s, numerous coral communities were devastated, presumably following an outbreak of *A. planci* in the Masqat area and Jaza'ir Daymaniyat in 1978-1979. Many reefs dominated by acroporids suffered close to 100% mortality, but the majority of *Porites* and *Pocillopora* reefs survived. At the time of the survey by Glynn (1983), moderate numbers of *A. planci* (30-60 individuals/ha) were present and on damaged reefs, only limited recovery had occurred over three years. A small (c. 2000 sq. m) *Acropora* community at Qantab, south-east of Masqat, contained mainly dead colonies. *Acanthaster* was seen feeding on acroporids, *Montipora* and *Stylophora*, but *Pocillopora, Porites, Astreopora* and *Goniopora* were generally avoided. Recently, *Acanthaster* have been seen feeding on *Pocillopora* at numerous sites and to a lesser extent on *Porites, Platygyra* and *Goniopora* (Salm and Sheppard, 1986). The rarity of *Acanthaster* on the Arabian Sea coast could be due to detrimental effects of cool water on its larval development.

There are few reports of human disturbance, but fishermens' nets, when set in shallow bays such as around Ra's Abu Da'ud, come up entangled with live colonies of *Pocillopora damicornis* (Salm and Sheppard, 1986). In the Capital Area, basket traps pose a threat to territorial reef fish; reefs which are heavily trapped lack large groupers. Fishermen seem to be aware of this and periodically shift all their traps to different reefs (Salm, 1986a).

The coast is potentially threatened by pressure from recreational use, littering and collection of marine curios. There has been some illegal spearfishing. Larger varieties of shell are absent from areas frequently visited by divers and there is a contingent of foreigners who methodically strip the reefs of pearl oysters. One local fisherman sells shells to foreigners between Seeb Beach and Ra's al Hamra, particularly *Lambis truncata*. Shells are also sold in the Mutrah suq (Salm, 1986a). Spiny lobsters, *Panulirus versicolor*, the more northerly species, and especially *P. homarus* the southern species (which is heavily fished in the Zufar region, mainly at Liqbi and Raykyut), are overexploited (Clarke *et al.*, in press; Sheppard, 1986b). As yet there is no evidence of overexploitation of the abalone in the Southern region but increasing commercial pressure could lead to serious depletion (Barratt, 1984).

Oil pollution is not a threat at present but areas vulnerable to spills, through their proximity to tanker traffic routes, oil loading facilities or shipping hazards, include Qur'm Public Park and Nature Reserve, Jazirat al Fahl, Jaza'ir Daymaniyat and the Sarooj to Qur'm and Ra's al Hamra beaches (Salm and Dobbin, 1986). Sand mining at two sites east of Barka and close to Bayt al Barakah has caused some coastal erosion but has had no known effect on the reefs (Salm, 1986a).

**Legislation and Management**

The Government of Oman has recognised the potential environmental problems arising from the rapid development of the Sultanate. Concerned that developments will not destroy coastal and marine environments and resources, it has taken specific actions to counter this. Some of these are described below and specific projects which include protecting and managing the reefs are described in the following accounts. Early efforts include a marine resources development programme drawn up by Mardela International Ltd (1975).

The Council for the Conservation of the Environment and Prevention of Pollution (CCEPP), set up by Decree No. 68 in March 1979, under the Chairmanship of HM The Sultan, is actively working against marine and industrial pollution. The Ministry of Environment was formed by Royal Decree on 15 May 1984. On January 1st 1986, the Council for Conservation of the Environment and Water Resources was formed from the CCEPP and Water Resources Council and the ministry was renamed the Ministry of Environment and Water Resources (MEWR) (Salm and Dobbin, 1986).

Oman has ratified the Kuwait Regional Convention for Co-operation on the Protection of the Marine Environment from Pollution and there are a number of efforts under way to protect coastal resources as part of the Kuwait Action Plan. It is a signatory to the London Dumping Convention. A series of laws issued by Royal Decree provide for the control of marine pollution (No. 34, 1974), the setting up of National Parks and Protected Nature Reserves (No. 26, 1979), the protection of marine resources (No. 53, 1981) and the protection of the environment and the prevention of pollution (No. 10, 1982). Pollution and sewage treatment standards have been defined for industrial and urban developments. Marine and air pollution are carefully monitored and a rapid response oil spill contingency plan has been prepared by the Ministry of Communications. Petroleum Development Oman (PDO) has good facilities for rapid oil containment and dispersal at Mina al Fahal. Beyond this area, the Royal Oman Police assume responsibility for oil spill containment.

Environmental impact assessments and "No Environmental Objection" decisions by the Ministry of

Environment and Water Resources are required for all new developments. Stretches of coast have been reserved for tourism. The "Coastal Reserve" of the Ministry of Housing aims to protect all beaches, where possible, to 200 m in from the high water line. These should remain undeveloped and open for recreation but public access is limited on private beaches and those closed for security reasons (Salm and Dobbin, 1986).

Several clauses designed to protect the marine environment are included in the Law of Sea Fishing and Protection of Marine Biological Wealth, Royal Decree No. 53, 1981. There are restrictions on potentially destructive fishing gear and on fishing operations in certain areas. Regulations control the efficiency of certain types of fishing gear, some fishing operations are restricted during certain seasons, and there are provisions for designating all marine mammals and sea turtles as protected species in Omani waters. Commercial exploitation of turtles is prohibited although some subsistence hunting is tolerated. A Royal Decree of 1976 controls the take of spiny lobsters (Clarke *et al.*, in press) although this legislation is rarely implemented. Spearfishing is prohibited. The collection of living molluscs is prohibited under regulations decreed by the Minister of Agriculture and Fisheries (Salm, 1986a).

Two small coastal nature reserves were established in the 1980s. The Sultan Qaboos Public Park and Nature Reserve, now renamed the Qur'm Public Park and Nature Reserve, is described in a separate account. The Khawr Salalah Bird Sanctuary is a coastal lagoon in the southern province of Zufar and does not include reefs. Jaza'ir Daymaniyat (*see separate account*) are protected on account of their important seabird nesting colonies.

A Marine Science and Fisheries Centre, with a fisheries laboratory, aquarium and museum, has recently been completed under the supervision of the Ministry of Agriculture and Fisheries and will concentrate initially on fisheries related research with possibly a Unesco supported ecological component (Ormond, 1984; Sheppard pers. comm., 1986).

**Recommendations**

IUCN has executed two projects in the coastal area supported by the Government of Oman. A Coastal Zone Management Project (IUCN Project 9070) has identified conservation areas in the Capital Area, from Ra's as Sawadi in the west to Quriyat in the east, including the offshore islands, and proposed management strategies (Salm, 1986a; Salm and Dobbin, 1986). The Capital Area Coastal Zone Management Plan will be integrated with the policies and plans of the Ministry of Housing and will include a Coastal Development Policy. It will also be integrated with the results of IUCN Project 9069 which is producing a Protected Areas Systems Plan for the entire coast (Anderlini, 1985; Sheppard, 1986a). A number of sites of biological importance have been identified and recommended for protected status. This project will also lead to the establishment of the necessary laws and institutional authority and to the provision of technical expertise. A Directorate General of Wildlife and Nature Conservation has been recommended to manage the wildlife and conservation programme under the Ministry of Environment and Water Resources. A Nature Conservation Policy and legislation for protected wildlife has been drafted (Sheppard 1986a; Clarke *et al.*, in press). The Government of Oman has contracted IUCN to study a further 600 km of coast and prepare coastal zone and conservation management plans for areas identified in the Protected Areas Systems Plan. This will link the Coastal Zone Management Plan with similar planning being undertaken in the southern region of Zufar.

Three types of protected areas have been proposed: National Nature Reserves, National Scenic Reserves and National Resource Reserves (Clarke *et al.*, in press). In National Nature Reserves, land use and development is to be controlled and managed by the new Directorate General, and permanent settlement unrelated to management is to be excluded. These would be the most important reserves for nature conservation and would be zoned for strict protection, general management and utility purposes. In National Scenic Reserves and National Resource Reserves, human settlement and the development of an associated infrastructure would be allowed and the Directorate General would only have partial powers. National Scenic Reserves would have Managed Zones and Monitored Zones. The main purpose of National Resources Reserves would be to restrict land use and development until such time as sufficient data have been obtained for resource management plans to be prepared. They would thus have a temporary status.

The following areas which include or are adjacent to coral reefs have been recommended as part of the proposed protected areas system (91 areas in total) by Clarke *et al.* (in press) and Salm and Dobbin (1986):

* = first priority for active management
** = second
*** = third

*Musandam Peninsula (see separate account)*:

1. Al Salamah National Nature Reserve ***
2. Fanaku National Nature Reserve ***
3. Bu Rashid National Nature Reserve ***
4. Kachalu National Nature reserve ***
5. Jazirat Musandam National Nature Reserve ***
6. Jazirat al Khayl National Nature Reserve ***
7. Jazirat Abu Sir National Nature Reserve ***
8. Musandam Peninsula National Scenic Reserve **
9. Jazirat Umm al Ghanam National Scenic Reserve ***
10. Jazirat Hamra National Nature Reserve ***
11. Jabal Letub National Nature Reserve *
12. Jazirat Umm al Fayyarin National Nature Reserve *
13. Jazirat Habalayn National Nature Reserve **
14. Sal al a'la National Nature Reserve **
15. Musandam National Resource Reserve *

*Capital Area*:

16. Ra's as Sawadi National Recreation Area and Scenic Reserve (*see separate account*) *
17. Jaza'ir Daymaniyat National Nature Reserve (*see separate account*) *
18. Qur'm-Al Fahl National Nature Reserve (Clarke *et al.*, in press; Salm and Dobbin, 1986) (to include the existing Qur'm Public Park and Nature Reserve) (*see separate account*) *

19. Bandar Jissah National Scenic Reserve and Recreation Area (*see separate account*) *
20. Bandar Khayran National Nature Reserve (*see separate account*) *
21. Ra's Abu Da'ud (Jabal Abu Da'ud) National Scenic Reserve (*see separate account*) **
22. Jabal Bani Jabir National Scenic Reserve; an area in the Eastern Hajar in the northern mountains extending to the coastal environment which includes the Ra's Qalhat coral reefs **

*Jazirat Masirah* (*see separate account*):

23. East Masirah National Nature Reserve *
24. South Masirah National Nature Reserve *
25. Masirah Straits National Nature Reserve *
26. Barr al Hikman National Nature Reserve; to include the entire peninsula and extensive areas of shallow water (2880 sq. km). *
27. Az Zahr National Scenic Reserve; would include the Ra's Madrakah coral communities. **

*Kuria Muria Islands* (*see separate account*):

28. Al Qibliyah National Nature Reserve *
29. Al Hallaniyah National Nature Reserve **
30. As Sawda National Nature Reserve **
31. Al Hasikiyah National Nature Reserve *
32. Sadh National Nature Reserve; on the Mirbat coast, east of the Salalah plain; to include mixed algal and coral communities. **
33. Mirbat National Nature Reserve; to include Wadi Zead Bay (*see separate account*). *

Some of the other proposed coastal reserves on the Zufar coast may include coral-algal assemblages.

Under the Coastal Zone Management Plan for the Capital Area, twelve recreational beaches have been proposed for management by the Department of Tourism as National Recreation Areas (prime beaches and those adjoining areas of outstanding scenic beauty), Managed Recreation Areas (generally in developed areas) or Wilderness Recreation Areas (in undeveloped areas with no facilities). National Recreation Areas have been proposed at Ra's as Sawadi and the main bay at Bandar Jissah (Salm and Dobbin, 1986). Guidelines for preventing serious damage during coastal development are given in Salm (1986b).

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## BANDAR JISSAH PROPOSED NATIONAL SCENIC RESERVE AND NATIONAL RECREATION AREAS

**Geographical Location** 10 km south-east of Masqat; 23°32'N, 58°42'E.

**Area, Depth, Altitude** The bay covers 2.3 sq. km, including islands and headlands; National Scenic Reserve to cover 7 sq. km; depth 1-17 m; max. alt. 100 m.

**Land Tenure** Government-owned.

**Physical Features** Precipitous undercut cliffs border most of the bay, which is divided into several sheltered coves with small sand beaches at the head of each. A large island in the north partially blocks the mouth of the bay and a second island lies deeper in the bay. A large and beautiful beach (400 m long) borders the inland end of the main body of the bay (Salm, 1985a).

**Reef Structure and Corals** The fringing reefs are small and are dominated by *Porites* or a *PoritesPlatygyra* assemblage. Living coral reefs fringe the shores in short stretches in the easternmost cove and around the south and east sides of the central island. In addition, there are several banks of coral rubble representing the sites of once living reefs of branching corals, mainly *Acropora*. Thirty coral genera and 41 species have been recorded making Bandar Jissah one of the richest areas for coral species in the Capital Area (Salm, 1985a). An early description of this area (Lorimer, 1908) suggests that coral growth was less significant then.

**Noteworthy Fauna and Flora** Reef fish are varied and abundant. The ten small beaches adjacent to and including Bandar Jissah are intensively used by nesting Green Turtles *Chelonia mydas* and Hawksbills *Eretmochelys imbricata* (total estimate 50-70 turtles). The 200 m at the head of the eastern cove has a area of the seagrass *Halodule* close off shore on which Green Turtles feed at high tide. Sooty Falcons, Red-billed Tropicbirds, Roseate Terns, White-cheeked Terns and Little Green Herons (*Falco concolor, Phaethon aethereus, Sterna dougallii, S. repressa* and *Butorides striatus*) nest in the cliffs in the North Island. Osprey *Pandion haliaetus* are resident through the winter (Salm, 1985a). The pearl oysters *Pinctada margaritifera* and *P. radiata* and the spiny lobster *Panulirus versicolor* occur (Clarke *et al.*, in press).

**Scientific Importance and Research** The area is an important turtle and seabird nesting area and the different reef types accessible from the Capital Area offer good opportunities for research and teaching. It has been surveyed by Salm (1985a) and part of the area was surveyed by Glynn for *Acanthaster* (Glynn, 1983; Salm *in litt.*, 10.2.85)

**Economic Value and Social Benefits** Fishermen from Qantab regularly set their nets and basket traps in or adjacent to the bays and use the smaller beaches to land and clean their nets and traps (Salm, 1985a). As the most beautiful natural area close to the capital, and with both land (via a single access road, 10 minutes drive from Masqat) and sea access, it is a very important recreation area and is used for picnicking, sunbathing, beachcombing, swimming, windsurfing, boating, waterskiing, SCUBA diving and snorkelling. Hundreds of visitors regularly make use of the area, particularly Omani nationals (Salm, 1985a; Salm and Dobbin, 1986). There are some interesting archaeological sites (Clarke, *et al.*, in press; Salm and Dobbin, 1986).

**Disturbance or Deficiencies** The reefs were affected by *Acanthaster* in the early 1980s. A small *Acropora* community had 50% dead coral colonies, with several *Acanthaster* individuals feeding on colonies (Glynn, 1983). Two small patch reefs of *Pocillopora damicornis* are dead (south-west of North Island and north of the large headland to the east of the central island) although the frame-building corals are still in position, overgrown by algae and soft corals. These areas are now being recolonized (Salm and Sheppard, 1986).

The proposed construction of a marina in the bay could have had significant detrimental effects (Salm, 1985a) and so it has been suggested that this should be constructed at Al-Bustan instead (Salm, 1985b). There is a natural loss of turtle egg clutches by fox and crab predation and through flooding by high tides and occasionally freshwater run-off from rocks during heavy rainfall. Dumping and burning of litter in turtle nest pits kills eggs and hatchlings. Littering of the beaches is a major problem despite signs and rubbish bins (*see below*). Other problems include accumulation of litter on reefs and destruction of reefs by gill nets (Salm, 1985a).

**Legal Protection** Royal Decree No. 33, 1978, prohibits development of Bandar Jissah by reserving the use of coastal lands between Sidab and Khayran for tourism (Salm, 1985a).

**Management** The Tourism Department have put signs on the main beach prohibiting littering and driving of vehicles on the beach (Salm, 1985a; Salm and Dobbin, 1986). The Capital Municipality has cleaned up the beach and placed rubbish bins there (Salm, 1985a).

**Recommendations** The area has been identified as a high priority for protection and a zoning and management plan has been prepared (Salm, 1985a; Salm and Dobbin, 1986). The management goal is to integrate tourism with conservation of the reefs, wildlife and the site's natural beauty. The Fisheries Department plans to ban all fishing in the bay (Salm *in litt.*, 10.2.85). It is recommended that the area should be managed intensively for recreational and tourism uses. Until the designation of a national authority for the management of all conservation areas, the Department of Tourism should assume total responsibility for active interim management. A zoning system has been proposed (Salm, 1985a) which includes: a Swimming Area off the main beach, managed for bather safety; a Controlled Access Area, permitting different recreational activities but where access and speed of motorized craft would be limited; an Unrestricted/Intensive Use Zone for high speed watersports; a Utility Zone to provide essential services to visitors, a site office and staff quarters; a Historical Site to preserve the village ruins and Scenic Walks to diversify recreational options. The proposed boundary follows the crests of major jebel systems and encloses the minimal ecological unit required for control of water flow and sediment transport into the Bandah Jissah ecosystem. The following activities need immediate implementation: aquisition of lands, design and construction of appropriate facilities including mooring buoys; printing and distribution of information brochures; improved litter control; hiring and training of staff, purchase of a boat and preparation of a detailed management plan (Salm, 1985a). National Recreation Areas will be discrete areas lying within the National Scenic Reserve (Clarke *et al.*, in press).

## BANDAR KHAYRAN PROPOSED NATIONAL NATURE RESERVE

**Geographical Location** 18 km south-east of Masqat; 23°31'N, 58°45'E.

**Area, Depth, Altitude** About 2.7 sq. km (submerged area); proposed National Nature Reserve will cover 14 sq. km; depth 1-24 m (average about 13 m); altitude 74 m, surrounding headlands reaching about 154 m;

**Land Tenure** Principally Government-owned. The Department of Tourism owns the large North Island and some land bordering the inland margin is settled by small-scale farmers and fishermen.

**Physical Features** The bay of Bandar Khayran consists of four main branches. The western branch connects to the sea and has an average depth of about 16 m. Reefs fringe parts of the rocky western shore and the entire southern shore. The small islet in the east-central part of this branch is rocky and deeply undercut at the waterline and has a well-developed fringing reef. The western branch runs south into the southern or inland branch which is shallower (average depth less than 1 m) and has extensive flats of sand and mud exposed at low tides along its southern shore. The central branch is affected most by waves and swell driving in from the north as it opens to the sea where depths vary between 14 and 30 m; in more sheltered areas depths average 6-8 m. The eastern branch is divided from the central portion by a long rocky island and is connected by a shallow channel which is largely blocked at low tide by a sand bar. This branch is generally shallow (3-8 m deep) and has several patch reefs and fringing reefs along the central parts of the east and west shores.

**Reef Structure and Corals** The reef which fringes the islet in the western branch of the bay supports diverse, colourful and largely intact coral colonies. The reef slopes to sand at about 8-9 m depth, except off the east side where it is shallower; off the west, a flat-topped *Porites* platform extends out for about 100 m before the reef slope which drops to sand at 12 m depth. The fringing reef is generally covered with a mixed assemblage of coral genera, although parts may be dominated by vast fused *Porites* colonies and patches of other corals such as *Acropora*. The southern shore of the western branch is fringed with an incipient reef 200 m long, formed exclusively of two tabular (reaching 1-2 m in diameter) and two ramose species of *Acropora*. Tabular species dominate from the intertidal to 8 m depth and ramose species from 8 to 10 m depth. There is about 100% living coral cover (Salm and Sheppard, 1986).

The central branch of the bay has several small patch reefs dominated by *Pocillopora* and *Acropora* particularly off the south shore of the large northern island. Patch reefs in the eastern branch of the bay are variable, some dominated by *Pocillopora*, others by *Montipora*. The largest is in the centre of the bay and is dominated by *Montipora* centrally with a fringe of *Acropora* at 4 m depth in the east and south-east. It slopes to 5-6 m depth from the south-west to the north-west, and is fringed with patches of *Astreopora* in the south-west, *Hydnophora* in the central-west and *Platygyra* in the north-west. *Anomastrea* is particularly common on the west slope and the sea urchin *Diadema setosum* is abundant. A total of 55 coral genera have been recorded from this area (Salm and Sheppard, 1986).

**Noteworthy Fauna and Flora** The White-cheeked Tern *Sterna repressa* nests on the small central island and Sooty Falcons *Falco concolor* nest in the area (Salm and Dobbin, 1986). The Pearl Oysters *Pinctada radiata* and *P. margaritifera* and the spiny lobster *Panulirus versicolor* are fairly common. Green *Chelonia mydas* and Hawksbill *Eretmochelys imbricata* Turtles nest on the beach south of the headland of Ra's al Khayran (Salm, 1986a). Well developed stands of the mangrove *Avicennia marina* fringe much of the shoreline of the southern branch of the bay particularly in the south-west and south-east.

**Scientific Importance and Research** The reefs are largely unspoiled compared with those closer to the capital and include two of the most important coral areas in Oman, the fringing reef off the islet in the bay and the fringing reef along the southern shore of the main bay (Salm and Sheppard, 1986). It has been identified as a site or area of scientific interest (Clarke *et al.*, in press). There are four identified archaeological sites, and probably more, of which three are of great age (possibly to 4000+ years BC) and interest; these are yet to be studied (Salm and Dobbin, 1986).

**Economic Value and Social Benefits** There is a small fishing village at the head of the bay. Fishermen collect bivalves from the shores and fish in the bay and adjacent ocean. The area is visited by boaters at the weekend for diving, water skiing, camping and picnicking and to a lesser extent by campers arriving overland. The Tourism Department have plans to build a resthouse and small restaurant, and a jetty adjacent to the small south-east cove on North Island for use by boaters (Salm and Dobbin, 1986).

**Disturbance or Deficiencies** There are few disturbances at present, although there is evidence of damage from gill nets entangled in corals and anchors in the western branch of the bay (Salm *in litt.*, 18.3.85) and recent evidence of damage to corals by divers. The area is regularly visited by expatriates spearfishing illegally (Salm *in litt.*, 16.12.86).

**Legal Protection** None.

**Management** Currently none.

**Recommendations** The area has been proposed as a National Nature reserve under the Capital Area Coastal Zone Management Plan, adjoining, at its southern end, the proposed Jabal Abu Da'ud National Scenic Reserve (Clarke *et al.*, in press; Salm and Dobbin, 1986). It would be managed to retain its scenic beauty and values for wildlife, recreation, archaeology and fisheries. Detailed management recommendations are given in Salm and Dobbin (1986). The Fisheries Department plan to ban fishing in some or all areas of the bay (Salm *in litt.*, 10.2.85). Proposals for protection and management of the area will be submitted as part of the IUCN Coastal Zone Management project.

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## JAZA'IR DAYMANIYAT (DAYMANIYAT ISLANDS) PROTECTED AREA AND PROPOSED NATIONAL NATURE RESERVE

**Geographical Location** Gulf of Oman about 16 km north of the Seeb-Barka (or south-eastern Al Batinah) coast; 23°45'N, 58°10'E.

**Area, Depth, Altitude** Total land area is about 85 ha; boundaries of proposed National Nature Reserve enclose a rectangle of 203 sq. km.

**Land Tenure** Government-owned.

**Physical Features** The nine islands stretch for 20 km in an east-west direction with numerous satellite rocks, reefs and shoals and are formed of emergent limestone rock and fossil reefs. Except for the easternmost one, which rests on a shoal, they tend to have cliffed north faces from which they slope southwards to the sea. The northern cliffs continue underwater as sheer drops or steep rocky slopes to 20-25 m depth. To the south, the islands are bordered by wide shallow shelves of sand and coral, with occasional coral-bound rocky outcrops (Salm, 1986c).

**Reef Structure and Corals** Patch reefs and fringing reefs are well developed along the lee (south) sides of the island chain. *Acropora, Montipora, Pocillopora* and *Porites* occur abundantly. However, in many cases the reefs are largely dead, live coral cover being as low as 1%, although some coral formations, dominated by *Pocillopora* and *Porites*, have coral cover well over 50% and even 100%. A few mixed *Acropora Pocillopora* formations, with nearly all the *Acropora* dead and all the *Pocillopora* alive, indicate a highly selective mortality. Live corals occur at a maximum depth of about 15-20 m while the dead *Acropora* patch reefs are shallower (2-5 m). Vertical framework construction of the reefs is slight (1-3 m), suggesting a very youthful stage of development. *Porites* fringing reefs show a vertical framework development of 4-5 m while the larger *Pocillopora* patches reach 6-7 m in thickness. The latter are elongate, and develop along the leeward edge of the shallow shelf break (4-5 m depth) where they gradually descend into deeper water, stopping abruptly at a gently sloping sand plain at 10-12 m depth. Coral communities are well developed at two sites on the exposed north side of the islands but maximum development of the reef framework is only about 2 m thickness (Glynn, 1983). There is a coral patch, 40 x 10 m in area and 1 m thick, south of Jazirat Jun, the more easterly group of islands, which is unique in being built exclusively of *Galaxea*. *Galaxea* colonies in Oman are usually much smaller in area (Salm, 1986c).

The islands offer a variety of habitats for coral settlement including underwater cliffs, ledges and overhangs, shallow rocky shelves and rock outcrops in both exposed and sheltered locations. The diversity of corals is therefore relatively high (c. 30 genera and more than 40 species) (Salm, 1986c).

**Noteworthy Fauna and Flora** As a result of the islands being free of mainland predators, they are important nesting sites for Sooty Falcons, Red-billed Tropicbirds, Bridled Terns, White-cheeked Terns, Roseate Terns, Noddies, Sooty Gulls, Little Green Herons, Western Reef Herons and Ospreys (*Falco concolor, Phaethon aethereus, S. anaethetus, S. repressa, S. dougallii, Anous stolidus, Larus hemprichii, Butorides striatus, Egretta gularis* and *Pandion haliaetus*). Green Turtles *Chelonia mydas* and Hawksbills *Eretmochelys imbricata* nest (Salm, 1986c). Molluscs, including pearl oysters, are abundant and the islands are popular for shelling (Salm and Dobbin, 1986). Fish, plants and terrestrial fauna recorded in the area are listed in Salm (1986c).

**Scientific Importance and Research** Surveyed by Glynn (1983) and Salm (1986c) and considered one of the main coral areas in Oman (Salm and Sheppard, 1986).

**Economic Value and Social Benefits** Reefs and adjacent waters are fished by residents of the coastal villages on the mainland. During the open season the islands are used for weekend camping, picnicking, fishing (including for spiny lobsters) and diving, the easternmost and main islands being the most popular camping sites. The islands are also visited by worshippers as there are a number of religious sites (Salm, 1986c).

**Disturbance or Deficiencies** Some of the acroporid reefs were severely damaged by an outbreak of *Acanthaster* in 1978-1979 (Glynn, 1983), but are being recolonized by algae, alcyonarians, *Acropora, Pocillopora* and other corals (Salm and Sheppard, 1986). Litter is a problem on some beaches and also damages the reefs. Entangled nets have killed 25-85% of the coral colonies on patches of *Pocillopora damicornis*. Birds eggs are poached during the closed season and nesting ospreys are disturbed in the open winter season. Turtles are disturbed by campers, 3-5% of their eggs are collected, females are sometimes killed and turtle nesting pits are used for barbecues and litter disposal (Salm, 1986c). The islands are particularly vulnerable to oil spills, although there has been no damage so far (Salm and Dobbin, 1986).

**Legal Protection** The islands are closed from May to October during the seabird nesting season, as a result of a decision taken in 1984 by the Diwan of Royal Court Affairs.

**Management** Originally under the jurisdiction of the Office of the Deputy President for Agriculture, Stables and Housing Affairs (Diwan of Royal Court Affairs), the islands came under the Dept of Tourism in January 1987. There are four guards at all times, rotating weekly; guard accommodation has been built on the largest island and there is a boat for patrol work (Salm, 1986c).

**Recommendations** Proposed as a National Nature Reserve (Clarke *et al.*, in press; Salm and Dobbin, 1986). Detailed recommendations are given in the management plan for the proposed reserve (Salm, 1986c) and are summarized in the Capital Area Coastal Zone Management Plan (Salm and Dobbin, 1986). The reserve should fit into the national protected area system but, as recommended actions for this have not been accepted by the Government, it is suggested that the plan should be implemented as soon as possible and it has been designed for revision after two years. A zoning scheme has been proposed which includes a General Management Zone in which recreation, fishing and other approved activities are permitted subject to certain restrictions, and a Utility Zone on the main island for staff and visitor accomodation and administration and research facilities. Legislation is required and proposed draft regulations have been drawn up by Salm (1986c). Recommendations are made for the involvement of other agencies, such as the Ministry of Agriculture and Fisheries, the Ministry of Communications, the Sultan of Oman's Navy and the Royal Oman Police, in the management of the area.

The current staff, although adequate in number, urgently need training, suitable equipment and supervision (Salm, 1986c). The beaches need to be cleaned and increased efforts made to prevent disturbance of wildlife and control damaging recreational activities. An interpretive programme should be developed, traditional uses of the area should be studied with the aim of improving management and an oil spill contingency plan developed. Since the islands are considered particularly vulnerable to oil spills, special arrangements should be made to prevent damage in the event of an accident.

**KURIA MURIA ISLANDS PROPOSED NATIONAL NATURE RESERVES**

**Geographical Location** Off the south-east coast, in Kuria Muria Bay.

**Physical Features** The Kuria Muria Islands are small (1-10 km diameter) but mountainous, with numerous sheltered embayments, and are oriented east-west. Their geology is described by Clarke *et al.* (in press). Mean annual rainfall is probably less than 150 mm. Al Qibliyah, the most easterly island, is hilly (max. alt. 185 m) and is the only example of volcanic rock in the area. Al Hallaniyah is one of the central islands and has rugged terrain with a massive limestone cliff on the north-eastern side (max. alt. 500 m). As Sawda is west of Al Hallaniyah and is also rugged (415 m). Al Hasikiyah, further west is generally flat with a hilly portion at the southern end (155 m) (Clarke *et al.*, in press). The sublittoral substrate is a complex mixture of sand and rocks. Each island is surrounded by a broad area of shallow water less than 100 m deep, although they lie relatively close to the edge of the continental shelf.

**Reef Structure and Corals** There are no true reefs, although a few bays have a coral cover of over 80% to 10 m depth. A sparse coral assemblage and a community of brown macroalgae are found on hard substrates, commonly forming a mixed community, or else occuring separately over wide areas. No sites have been examined deeper than 10 m. Corals have been briefly examined by Sheppard (1986a).

**Noteworthy Fauna and Flora** The kelp *Ecklonia radiata* (known otherwise only from Australia, New Zealand, South Africa and adjacent parts of the Oman coast) occurs (Barratt, 1984). The Green Turtle *Chelonia mydas* nests on the islands (Clarke *et al.*, in press) and Hawksbills *Eretmochelys imbricata* and Olive Ridleys *Lepidochelys Olivacea* are occasionally seen. The Red-billed Tropicbird, Masked Booby, Bridled Tern, Crested Tern, Common Noddy, Audubon's Shearwater and the Socotra Cormorant (*Phaethon aethereus, Sula dactylatra, Sterna anaethetus, S. bergii, Anous stolidus, Puffinus lherminieri* and *Phalacrocorax nigrogularis*) breed on the islands (Gallagher, 1983 and 1985). Terrestrial fauna and flora are described in Clarke *et al.* (in press).

**Scientific Importance and Research** None, apart from a brief survey by Sheppard (1986a).

**Economic Value and Social Benefits** Fishing is the major activity on Al Hallaniyah which is the only inhabited island (Clarke *et al.*, in press)

**Disturbance or Deficiencies** There are feral cats and dogs on Al Hallaniyah, the former catching gulls (Gallagher, 1985). Fishermen and villagers also take birds and eggs (Gallagher *in litt.*, 13.12.86).

**Legal Protection** None.

**Management** None.

**Recommendations** The following protected areas have been recommended by Clarke *et al.* (in press):

- Al Qibliyah National Nature Reserve (8 sq. km)
- Al Hallaniyah National Nature Reserve (70 sq. km)
- As Sawda National Nature Reserve (20 sq. km).
- Al Hasikiyah National Nature Reserve (4 sq. km).

The reserves would include the islands and the surrounding marine environment 500 m out to sea beyond low water mark. The village of Al Hallaniyah would probably be the best locality at which to base all management personnel who would be responsible for the four reserves. It is fairly central, water and other amenities are available, and facilities exist for landing craft and docking boats. In general the islands, and particularly their marine fauna, are protected through their isolation and inaccessibility and the local people are conservation-minded, although seabirds need protection (Barratt *in litt.*, 15.1.87).

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**JAZIRAT MASIRAH (MASIRAH ISLAND) PROPOSED NATIONAL NATURE RESERVES**

**Geographical Location** Off the east coast, opposite the Barr al Hikmann Peninsula, separated from the mainland by the 20 km wide Khawr al Masirah; 20°30'N, 58°45'E.

**Area, Depth, Altitude** about 60 x 10 km; max. alt. 280 m. To the west, maximum depths are 20 m while to the east the 100 m contour is about 10 km off shore.

**Land Tenure** On the eastern coast, the land is partly registered under the Ministry of Defence.

**Physical Features** The island is gently undulating with a central spine of hills and peripheral coastal plains. There are several small islets. The shallow western side is sheltered during monsoons and possibly retains higher water temperatures than the exposed, eastern side which experiences the cold upwelling effects to a greater extent. Mean annual rainfall is 110 mm but is very erratic (Clarke *et al.*, in press).

**Reef Structure and Corals** Reefs are generally poor and largely restricted to the sheltered western side. Fringing reefs dominated by platy *Montipora* have been found in the north-west; large patches of *Pocillopora* occurred both on the fringing reefs and off shore. *Acropora* was generally uncommon, while towards the south of the island, corals increasingly formed a mixed community with *Sargassum* (Anderlini, 1985; Glynn, 1983).

**Noteworthy Fauna and Flora** The largest concentration of Loggerhead Turtles *Caretta caretta* in the world nests on the east coast of Masirah, with an estimated 30 000 females coming ashore each May-September, mainly on Surf Beach. Green Turtles *Chelonia mydas* also nest here in appreciable numbers, particularly on Turtle Beach, while the Olive Ridley *Lepidochelys olivacea* and Hawksbill *Eretmochelys imbricata* are also important. The island has appreciable stands of mangrove *Avicennia marina* and feeding areas for thousands of shorebirds (Anderlini, 1985; Griffiths and Rogers, 1976). The shallow western side of Masirah is adjacent to the largest mud flats of Oman, the Bayad Dimnah, which is known for its seabird populations. Molluscs are described by Briggs (1969), Charter (1983), Smythe (1978) and Smythe and Gault (1980). Arabian Gazelle *Gazella gazella* and the endemic subspecies of hare *Lepus capensis jefferyi* occur. Houbara Bustard *Chlamydotis undulata* may visit the island in autumn. Seabirds include the Crested Tern, Roseate Tern, White-cheeked Tern and Bridled Tern (*Sterna bergii, S. dougallii, S. repressa* and *S. anaethetus*) which nest on islets, particularly Jazirat Shaghaf in the Masirah Straits (Clarke *et al.*, in press).

**Scientific Importance and Research** For several years the turtle populations have been monitored by research personnel of the Directorate General of Fisheries (Clarke *et al.*, in press).

**Economic Value and Social Benefits** Ra's al Hilf in the north and the associated SOAF base on the island have a population of about 5000. Fishing is the main activity (Clarke *et al.*, in press).

**Disturbance or Deficiencies** Anderlini (1985) and Clarke *et al.* (in press) report severe, recent disturbance and erosion of the Loggerhead Turtle nesting beaches from a construction camp which has been built inside the nesting beach boundary. Disturbance from Ministry of Defence activities was reported to be increasing daily, and alterations to the shoreline have resulted, with some prime nest sites being flooded. There may also be overcollection of some of the rarer and more valuable shells by local expatriates and fishermen (Smythe *in litt.*, 23.4.85).

**Legal Protection** Since 1978, fishing by trawlers has been prohibited in the area east of the island between 21°10' and 21°45'N (Zahran, 1981).

**Management** None.

**Recommendations** Anderlini (1985) recommended that several turtle nesting areas be protected. Clarke *et al.* (in press) have proposed the following areas:

- The north-eastern coast as the East Masirah National Nature Reserve (45 sq. km) to include Surf Beach and Turtle Beach.
- The southern half of Jazirat Masirah as the South Masirah National Nature Reserve (190 sq. km) to include a number of turtle beaches.
- The shallow sea in the Masirah Straits to the west of Jazirat Masirah as the Masirah Straits National Nature Reserve (860 sq. km), to include the western coast from Ra's al Hilf to Ra's Abu Rasas and the island of Jazirat Shaghaf, which urgently needs protection for its seabird population. This would adjoin the proposed South Masirah National Nature Reserve to the east and the proposed Barr al Hikman National Nature Reserve to the north-west.

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## MUSANDAM PENINSULA PROPOSED RESERVES

**Geographical Location** The northernmost part of Oman, separated from the rest of the country by part of the United Arab Emirates; 26°N, 56°30'E.

**Area, Depth, Altitude** The peninsula is about 50 x 100 km; water depths exceed 300 m within 1 km of land; altitude exceeds 1000 m.

**Land Tenure** Government-owned.

**Physical Features** The region is fjordic in nature, consisting of an extremely convoluted system of long, tortuous inlets, offshore islands and precipitous mountains and scree slopes. Since the Pleistocene it has been subsiding into the Straits of Hormoz, which has led to the formation of rias or submerged valleys that extend seawards from existing wadis. The sublittoral slopes are mostly very steep and are extensions of vertical and near vertical limestone cliffs rising to over 500 m immediately adjacent to the sea, although at the heads of the khawrs, such as south Khawr Niad, gravel and rubble occur on very gentle slopes. Cliff undercutting is extensive, generally caused in the main fjords by bioeroders rather than by wave action, although the latter has an impact in more exposed areas. Steep, sandy substrate often continues down from the steeper, solid limestone at 20-30 m depth. Depths of over 40 m are found close to shore in all areas. The fjord-like structure of eastern Musandam provides a wide range of marine exposures, ranging from extremely sheltered to very exposed to easterly winds. The western side, facing the Gulf, is much shorter and includes a large muddy area near the main town of Khasab (Clarke *et al.*, in press). Geological aspects are described in Cornelius *et al.* (1973). The mean annual rainfall at Khasab is 182 mm, most rain falling between December and March. Terrestrial features of the Peninsula are described in Clarke *et al.* (in press).

**Reef Structure and Corals** The western coast was studied by Glynn (1983) and the longer eastern coast by Anderlini (1985) and Sheppard (1986a and c). Corals dominate the sublittoral in most parts, although on the gentle, gravel slopes, zoanthids provide extensive cover on boulders. Coral cover is very variable, ranging from less than 10% to 100%, with no obvious pattern. Equally variable is the pattern of coral assemblages and wide range of different coral zonations, but several features are common to all sites. Coral cover is greatest in shallow water particularly in sheltered embayments where wind and wave action are reduced and visibility increased; *Acropora, Pocillopora* and, occasionally, *Porites* dominate. With increasing depth, these genera become scarce or absent and a higher coral diversity appears, although total coral cover declines due to increasing presence of sand at depths of between 15 and 30 m. *Pavona, Goniopora* and *Montipora* are found and live coral cover may reach 60% in shallower areas (Glynn, 1983). In the shallowest areas, calcareous red algae of the *Lithothamnion* group are abundant, often providing 10-20% cover.

True reef formation is rare although Glynn (1983) identified small fringing and patch reefs. Occasionally, there is sufficient build-up of massive species (especially *Porites*) in shallow water (2-4 m) to give a profile of a true reef, with a reef flat at low water level and a reef slope. In some areas, *Pocillopora damicornis* forms large monospecific banks which may be termed patch reefs. Mostly, however, the old bedrock is clearly visible and the corals merely form non-reefal assemblages on the old substrate (Glynn, 1983; Sheppard, 1986a).

Clarke *et al.* (in press) consider the following sites and areas of particular interest for their marine biota: Dawhat ash Shishah, Ghubbat ash Shabus, Khawr Habalayn, Jazirat Habalayn and North Limah Bay. Coral populations are most diverse and rich at Dawhat ash Shishah, a bay on the eastern side, which is slightly more protected from the prevailing winds and waves than other sites. Ghubbat ash Shabus is also protected and has diverse coral populations forming a veneer over the limestone, particularly at Ra's Bashin. *Acropora* sp. and *Pocillopora damicornis* dominate above 3 m depth; at greater depths, large areas are covered with *Echinopora gemmacea*, leafy pectiniids and a high diversity of other species. Khawr Habalayn, also on the east coast, has diverse coral populations, particularly at Zahuriyan and Nibah. These sites were briefly surveyed by Salm (1986d) who found that the corals were more varied and coral growth more prolific than in the Masqat area although there was less framework development and fewer large *Porites* boulders. Jazirat Habalayn, an island lying in the bay, has particularly high coral cover in the shallows and apparently true reef construction, although there is a limestone substrate. From low water to 1.5 m depth, there is total cover of *Porites* sp. forming a reef flat. From 1.5 m to 4 m depth there is almost total cover of tabular *Acropora* sp. Below 4 m there is a high diversity of coral, which ends at about 25 m depth, where sand cover reaches 100%. North Limah Bay, on the east coast, has a shallow reef extending from the north along the coast and into the bay; it is dominated by a soft coral *Sarcophyton* (80%) and a species of *Heliopora* (Clarke *et al.*, in press).

Zoanthids dominate the gravel areas at the head of Khawr Nida. Black coral *Antipathes* sp. was recorded at several sites (Clarke *et al.*, in press) and *Cirripathes* is common below 30 m (Sheppard, pers. comm., 1986).

**Noteworthy Fauna and Flora** This area is isolated from other hard substrate, coral-populated sites in the Indian Ocean by about 1000 km of coast with soft substrate. It is therefore an important nursery area for fish, and large schools of typically reef fish occur here. Turtles are uncommon, and Dugong *Dugung dugon* have not been reported. The Osprey *Pandion halieutus* occurs and may be a breeding resident. The offshore islands in the Straits of Hormoz may be breeding sites for the Red-billed Tropicbird *Phaethon aethereus* and the Socotra Cormorant *Phalacrocorax nigrogularis* may use them for summer roosting. Jazirat Umm al Fayyarin, 6 km east of the peninsula in the Gulf of Oman, is a nesting site for the Red-billed Tropicbird, Osprey, Bridled Tern *Sterna anaethetus*, Sooty Tern *S. fuscata* and Common Noddy *Anous stolidus*. Sal al A'la, a mountainous area in the south-east of the peninsula is considered particularly rich in wildlife (Clarke *et al.*, in press).

**Scientific Importance and Research** Little work has been done on this area apart from preliminary surveys (Anderlini, 1985; Cornelius *et al.*, 1973; Falcon, 1973; Glynn, 1983; Sheppard, 1986a). There is a small fisheries department in Khasab.

**Economic Value and Social Benefits** The small population depends mainly on fishing, the main fishing village being Kumzar. The coastal villages are occupied in the cooler months (September to March), villagers migrating to other communities in the summer. Access is by boat only. The islands are uninhabited apart from Jazirat Umm al Ghanam which is a naval base (Clarke *et al.*, in press).

**Disturbance or Deficiencies** Corals appear to be subject to frequent disturbances by rock slides. Large sections of steep, limestone cliffs often give way, resulting in rock piles that cover the adjacent submarine shelf. In some cases there has been successful recolonization and growth of corals (Glynn, 1983). Salm (1986d) found fairly high densities of *Acanthaster planci* at Nibah and Zahuriyan in Khawr Habalayn; 25% of the *Acropora* community appeared to have been damaged at the latter site. There is little disturbance to the reefs from human activities. Jazirat Umm al Fayyarin is used for gunnery practice but the reefs are not affected (Clarke *et al.*, in press).

**Legal Protection** None.

**Management** None.

**Recommendations** The following areas have been identified as suitable for protection (Anderlini, 1985; Clarke *et al.*, in press; Sheppard, 1986a):

- The Musandam Peninsula as a Landscape of Special Interest (Clarke *et al.*, in press).
- The northern half of the Peninsula as far south as the narrow waist east of Ghubb Ali, as a National Scenic Reserve, to include the small island group of Jazirat Sawda lying offshore in the bay of Dawhat ash Shishah and the adjacent sea and sublittoral habitats to a distance of 200 m beyond low water level.
- Jazirat Umm al Ghanam (except for its northern end which is occupied by a SON base), off the north-western end of the Peninsula, as a National Scenic Reserve to include the adjacent sea and sublittoral habitats to a distance of 200 m beyond low water level.
- Jazirat Hamra, in the bay of Dawhat ash Shishah, as a National Nature Reserve.
- The southern half of the Musandam Peninsula as the Jabal Letub National Nature Reserve, to include the islands of Jazirat Sibi, Jazirat Shamm, Jazirat al Maqlab and the small island off Ra's Kaysah; this will include the interesting coral communities in the bays of Ghubbat ash Shabus and Khawr Habalayn.
- The mainland area, south from the proposed Jabal Letub National Nature Reserve and Sal al A'la National Nature Reserve as a Musandam National Resource Reserve, to include the coast area (apart from human settlements), the island of Jazirat Limah, and some other small islets (Clarke *et al.*, in press).

Other proposed National Nature Reserves in the area include the following islands in the Straits of Hormuz: Al Salamah, Fanaku, Bu Rashid, Kachalu, Jazirat Musandam, Jazirat al Khayl, Jazirat Abu Sir, Jazirat Umm al Fayyarin, Jazirat Habalayn (within Khawr Habalayn), and Sal al A'la, a mountainous coastal area south of Khawr Habalayn.

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## QUR'M (SULTAN QABOOS) PUBLIC PARK AND NATURE RESERVE AND PROPOSED QUR'M-AL FAHL NATIONAL NATURE RESERVE

**Geographical Location** Capital Area coast, west of Masqat; about 23°40'N, 58°30'E.

**Area, Depth, Altitude** 10 sq. km; Jazirat al Fahl (Fahal Island) lies 4 km off shore.

**Land Tenure** Government-owned.

**Physical Features** The area includes the Qur'm creeks, beach, mangroves and associated sabkha, acacia woodland and rocky shores of Ra's al Hamra and extends seawards to include the seabed, reefs and Jazirat al Fahl (Salm and Dobbin, 1986). The vertical limestone strata of the mainland peninsula opposite Jazirat al Fahl dip seawards and protrude from the sandy substrate as a series of low parallel underwater ridges (Salm and Sheppard, 1986).

**Reef Structure and Corals** Jazirat al Fahl is surrounded by diverse coral communities, including incipient patch reefs dominated by *Pocillopora damicornis* and mixed coral assemblages on underlying base rock. A total of 36 coral genera have been recorded, an unusually high number for such a small area (Salm and Sheppard, 1986). Three rock outcrops in depths of 17-25 m, 20-35 m and 22-42 m are the only location in the Capital Area for the deep water coral genera *Phyllangia, Rhizopsammia, Polycyathus* and *Madracis*. Other corals which are rare in the Capital Area are also found here in abundance, such as *Leptoseris, Culicia smithi* and *Balanophyllia*. The submarine ridges off the mainland also support unusual coral growth, including large colonies of *Turbinaria* (1-1.5 m diameter) and *Anomastrea*, and numerous *Turbinaria peltata* colonies. This is the sole location in the Masqat area of the new species *Acanthastrea maxima* whose polyps reach 10 cm in diameter. Beds of the free-living *Heteropsammia cochlea* have so far only been found on the sandy substrate between Jazirat al Fahl and the mainland, although it may yet be found elsewhere. This sandy area may prove to be another significant coral area.

**Noteworthy Fauna and Flora** Jazirat al Fahl is the most important nesting area for Sooty Falcons *Falco concolor* in the Capital Area. Red-billed Tropic Birds *Phaethon aetherus* also nest there. There is a well developed stand of mangrove at Khawr Qur'm (Clarke *et al.*, in press; Salm and Dobbin, 1986). The spiny lobster *Panulirus versicolor* occurs. Molluscs are described by Smythe (1984).

**Scientific Importance and Research** The rock outcrops around Jazirat al Fahl have the best examples of deep water corals in the Masqat area. The area is the centre of coral diversity of the Capital Area, all but three of the known Masqat area genera occurring here. This is largely due to the great variety of suitable habitats (Salm and Sheppard, 1986). Petroleum Development Oman (PDO) carried out a survey at Mina al Fahl (Ansell *in litt.*, 8.12.86).

**Economic Value and Social Benefits** Jazirat al Fahl is the most popular diving site in the country (Salm and Dobbin, 1986). Some interesting archaeological sites occur within the area (Clarke *et al.*, in press; Salm and Dobbin, 1986).

**Disturbance or Deficiencies** Acroporid reefs around Jazirat al Fahl had died off but are now being recolonized by a variety of corals (Salm and Sheppard, 1986).

**Legal Protection** The Sultan Qaboos Public Park and Nature Reserve was established in the early 1980s and renamed Qur'm in 1986.

**Management** Qur'm Public Park and Nature Reserve is managed by the Municipality of the Capital Area. PDO has good facilities for rapid oil spill containment and dispersal at Mina al Fahl, adjacent to the proposed reserve. Mooring buoys have been placed at Mina al Fahl by PDO, who also protect Jazirat al Fahl (Clarke *et al.*, in press).

**Recommendations** Recommendations for the management of this area as a Public Park and National Nature Reserve are given in the Capital Area Coastal Zone Management Plan (Salm and Dobbin, 1986). Objectives include maintaining the mangrove, reef and island ecosystems in their natural state, providing education, research and environmental monitoring whilst permitting controlled recreational activities. Ra's al Hamra and Khawr Qur'm are considered SASIs by Clarke *et al.* (in press).

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## RA'S ABU DA'UD (JABAL ABU DA'UD) PROPOSED NATIONAL SCENIC RESERVE

**Geographical Location** Eastern part of Capital Area, 5 km north-west of Quriyat.

**Area, Depth, Altitude** Proposed Ra's Abu Da'ud reserve would cover 15 sq. km; proposed Jabal Abu Da'ud reserve would cover 350 sq. km; max. alt. 1200 m.

**Land Tenure** Government-owned.

**Physical Features** The Ra's Abu Da'ud area includes a rocky point, islet and adjacent beaches and reefs (Salm and Dobbin, 1986). Visibility is often poor (3-4 m) at certain times of year due to algal blooms of plankton (Glynn, 1983). The proposed Jabal Abu Da'ud reserve area includes the highlands east and north of the drainage system comprising Wadi al Hulw, Wadi Hayfadh, Wadi Salil and Wadi Mijlas. It will extend some 500 m off shore (Clarke *et al.*, in press).

**Reef Structure and Corals** A variety of reef types are found, including incipient patch or fringing reefs dominated by *Porites* and incipient patch reefs dominated by *Pocillopora damicornis* (Salm and Sheppard, 1986). Glynn (1983) described two pocilloporid reefs on the north side of the point in a channel between the island and mainland. The reefs nearest the mainland were dead. Maximum framework development was about 2-3 m. The pocilloporid reef on the lee side of the island was mostly dead, the only living sections being at the southern tip where the reef sloped to deeper water. There was a small fringing poritid reef at Khawr al Hair just inside the bay entrance which had predominantly massive *Porites* with some massive *Goniopora* corals and several small patch reefs dominated by *Porites* or *Pocillopora* and *Acropora* on a talus base.

**Noteworthy Fauna and Flora** Green *Chelonia mydas* and Hawksbill *Eretmochelys imbricata* Turtles nest on the beaches. This is the largest nesting colony of White-cheeked Terns *Sterna repressa* and Roseate Terns *S. dougalli* in the Capital Area. Sooty Falcons *Falco concolor* also nest here (Salm and Dobbin, 1986). The proposed Jabal Abu Da'ud reserve would include Arabian Gazelle *Gazella gazella* and Arabian Tahr *Hemitragus jayakari*. Pearl oysters *Pinctada margaritifera* and *P. radiata* and the spiny lobster *Panulirus versicolor* occur and it is a popular shelling area (Clarke *et al.*, in press).

**Scientific Importance and Research** No information.

**Economic Value and Social Benefits** The site is only accessible by sea, but is of great scenic beauty and recreational potential. There are unstudied archaeological sites (Clarke *et al.*, in press; Salm and Dobbin, 1986).

**Disturbance or Deficiencies** Monospecific banks of *Pocillopora damicornis* have been extensively destroyed and are being recolonized by algae, alcyonarians and other coral species (Salm and Sheppard, 1986). There is some damage to corals from nets (Salm *in litt.*, 18.3.85).

**Legal Protection** None.

**Management** None.

**Recommendations** Recommendations for the management of this area as a National Scenic Reserve are given in the Capital Area Coastal Zone Management Plan (Salm and Dobbin, 1986). Management objectives are to preserve the area for future sustainable use, particularly recreation. The reserve would adjoin the proposed Bandar Khayran National Nature Reserve to the north. Clarke *et al.* (in press) make recommendations for the larger proposed Jabal Abu Da'ud Scenic Reserve.

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## RA'S AS SAWADI (RA'S SUWADI) PROPOSED NATIONAL RECREATION AREA AND SCENIC RESERVE

**Geographical Location** West of Muscat, on the southern Al Batinah coast.

**Area, Depth, Altitude** 15 sq. km; the islands lie 700 m to 2 km off shore.

**Land Tenure** Government-owned.

**Physical Features** The area includes a sandy point, Khawr as Sawadi, extensive sabkha, beaches and a group of seven rocky islands, the as Sawadi Islets (Salm and Dobbin, 1986).

**Reef Structure and Corals** Mixed coral assemblages are found on underlying base rock (Glynn, 1983; Salm and Sheppard, 1986) but have not been described in detail.

**Noteworthy Fauna and Flora** The islands have the greatest concentration of nesting Western Reef Herons *Egretta gularis* in the Capital Area and Sooty Falcons *Falco concolor* also nest here. There are sparse seagrass beds (Salm and Dobbin, 1986). The Pearl Oysters *Pinctada radiata* and *P. margaritifera* and the spiny lobster *Panulirus versicolor* occur (Clarke *et al.*, in press).

**Scientific Importance and Research** No information.

**Economic Value and Social Benefits** This is one of the two most important areas for weekend Capital Area beach recreation and is a largely unspoiled area of great scenic beauty. The islands are very popular with shell collectors (Salm and Dobbin, 1986). There are interesting archaeological remains on two of the islands (Clarke *et al.*, in press; Salm and Dobbin, 1986).

**Disturbance or Deficiencies** The Jazirat as Sawadi have come under increasing pressure from visitors in recent years, as they are easily accessible and boats can be hired at the new car park on the spit. The nesting colonies of herons and falcons are threatened by visitors who loot the nests (Clarke *et al.*, in press; Walter, 1982).

**Legal Protection** None.

**Management** None at present.

**Recommendations** Recommendations for the management of this area are given in the Capital Area Coastal Zone Management Plan (Salm and Dobbin, 1986). The main management objectives are recreation and tourism; suitable facilities should be provided and the area should be marked, wardened and monitored. The Ra's as Sawadi National Scenic Reserve will adjoin the National Recreation Area (Clarke *et al.*, in press).

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## WADI ZEAD, INCLUDED IN THE MIRBAT NATIONAL NATURE RESERVE

**Geographical Location** On Mirbat Peninsula approx. 15 km east of Mirbat; 16°56'N, 54°48'E.

**Area, Depth, Altitude** South-easterly facing bay approx. 1 km wide by 1.7 km long. Maximum depth on seaward edge is 20 m in central bay; averages 9 m, reaching 12-18 m on outer edges.

**Physical Features** The dominant feature controlling the marine biota in the southern region of Oman is the south-westerly monsoon, an air flow which causes an upwelling of cold, clear, nutrient-rich water during the summer months. Temperatures of 18°C have been recorded at this site (Savidge *et al.*, 1986), accompanied by severe wave action. On many parts of the coastline further west, hard substrate descends to less than 10 m depth so that coral growth may be limited by substrate availability as well as by exposure and temperature. To the east, the sublittoral topography becomes steeper and hard substrates may be found over 30 m deep in the Sadh area. The local sublittoral topography largely determines the intensity of the upwelling event, and to the east of Wadi Zead the community is dominated by kelp and other algae. Unlike much of the Southern Region, the rock structure is metamorphic. Rocks outcrop the overlying sand and gravel plain, and at the seaward margins are interspersed by numerous embayments with a variety of different exposure levels. To the east the rocks form cliffs descending almost vertically to the sea and access to the coastline is limited to wadi outlets. Sublittorally, Wadi Zead is composed of three distinctly different reef complexes which effectively enclose the bay. The substrate of the central bay is predominantly sand with occasional coral outcrops overgrown with *Sargassum*. Towards the landward margins of the bay, reef formations are replaced by luxurious algal beds composed of *Sargassopsis zanardinii* and *Sargassum* sp. during the summer monsoon.

**Reef Structure and Corals** The longest reef system in Wadi Zead faces south-west. In the more sheltered areas, a form of *Acropora clathrata* dominates the shallow sublittoral below 2 m. A further zone beyond this, to about 12 m depth, has about 42 species with soft coral cover averages about 5% (Clarke *et al.*, in press). This complex extends seawards, becoming shallower, with a maximum depth of 9 m, but more diverse, and with an increase in soft coral cover. A smaller, more sheltered reef faces north-east and extends southwards to the mouth of the bay. It is also dominated by *Acropora* sp. in depths of about 2-4 m and has a more complex community with a low percentage of soft coral appears in deeper water. The third reef complex faces almost due south and is the most exposed. It occurs between 8 and 20 m depth and coral cover can be as high as 70% in places; massive formations of *Platygyra deadelea* and *Porites nigrescens* are common but are not apparent in the other formations. Coral communities have been briefly studied by Barratt (1985), Barratt (pers. comm.) and Sheppard (1986a).

**Noteworthy Fauna and Flora** In shallow locations (sublittoral fringe to 2 m depth), the large brown alga, recently redescribed as *Sargassopsis zanardinii* and endemic to the Arabian Sea, dominates the substrate (Nizamuddin *et al.*, 1986). Other conspicuous brown algae include several species of *Sargassum* and *Cystoseira myrica*. The kelp *Ecklonia radiata* (known otherwise only from Australia and New Zealand) has not been found, but is a feature of the deeper water sublittoral in the Sadh district. Fauna associated with these algae include the abalone *Haliotis mariae*, which is at the outer limits of its range, and the crayfish *Panulirus homarus*. Small groups of Humpback Dolphins *Sousa plumbea* are often seen and occasional Bottlenosed Dolphins *Tursiops truncatus*. Loggerhead Turtles *Caretta caretta* have been observed mating in shallow water nearby in March (Barratt pers. comm.). The area is not reknowned as a breeding/nesting region but is an important feeding ground for Bridled, Sandwich, Crested and Sooty Terns and Herring Gulls (*Sterna anaethetus, S. sandvicensis, S. bergii, Larus hemprichii* and *L. argentatus*). Audubon's Shearwater *Puffinus lherminieri* and the Socotra Comorant *Phalacrocorax nigrogularis* are both common visitors to the area and nest on the nearby Kuria Muria Islands (Gallagher and Woodcock, 1980). Terrestrial fauna and flora are described in Clarke *et al.* (in press).

**Scientific Importance and Research** Wadi Zead has the most complex assemblage of corals so far described on the Mirbat coast, although significant communities have been observed at Grindstone Bay and Ra's Shabana to the north-east. These are the only localities known to have reef complexes rather than scattered coral colonies (Barratt, 1984; Barratt *et al.*, 1986a and b).

**Economic Value and Social Benefits** There is a small seasonal fishing village to the west of Wadi Zead concentrating mainly on finfish caught by shallow water traps, by cast nest or by gill net from boats. The main subsistence fishing activities occur in the immediate post-monsoon period (September-December) when both abalone and crayfish are caught locally. Handlining from the rocks above the reef is common during the monsoon; other fishing is limited to shallow water inshore traps at this time. Abalone and crayfish numbers are too small for commercial interests (Barratt pers. comm.).

**Disturbance or Deficiencies** Crayfish populations are already overfished to near exhaustion west of Salalah (Sheppard 1986b) and commercial activities are now concentrated off the Al Jazir plain. There is little likelihood that commercial exploitation will reach the Mirbat-Wadi Zead region. There is no commercial fishery for abalone at Mirbat and the epicentre of this population is at Sadh. Damage to the corals by fishing activities (line and trap) has been observed by Barratt (pers. comm.), Clarke *et al.* (in press) and Sheppard (1986a) and recreational diving is beginning to have a negative impact.

**Legal Protection** None.

**Management** None.

**Recommendations** Wadi Zead Bay will be included in the proposed Mirbat National Nature Reserve. This will also include some of the adjacent land for general logistic purposes and to improve protection. The southern boundaries will run 500 m beyond the low water mark. The primary management goal is to conserve selected features of the environment both on land and at sea (Clarke *et al.*, in press).

# TANZANIA

## INTRODUCTION

### General Description

The coastal zone of Tanzania is a fairly narrow strip of land which extends from approximately 5 to 10°S (694 km) and has large, sweeping sandy beaches, 287 km in length, with rocky outcrops, steep limestone cliffs, fringing mangrove forests and areas with elevated, fossil reef. Hydrographic conditions are dominated by the seasonal monsoon winds and the South Equatorial Current. The latter reaches the African coast at, or just to the south of, Tanzania where it divides to flow both north and south. The northerly branch known as the East African Coastal Current continues north along the Tanzanian coastline. Water temperatures range from 25 to 28°C. Tides are semi-diurnal with a daily range varying from 1.1 to 3.2 m, which is high compared with many coral reef areas (Couper, 1983; Duing, 1970; Hamilton and Brakel, 1984). Annual rainfall is over 800 mm, most falling in the period between monsoons. Rivers draining the interior, particularly the Rufiji, flood twice yearly during the intermonsoonal rains and pour freshwater and sediments into the continental shelf area. This results in breaks in the fringing reef system where extensive mangrove stands occur. These physiographic factors impose marked seasonal patterns on the physical and chemical conditions of shallow reefs (Hamilton and Brakel, 1984).

About two thirds or 600 km of the country's shelf are covered with coral reefs (Kudoja, 1985) which are found in a wide variety of exposures and degrees of sedimentation. Major studies include Hamilton (1975) and Hamilton and Brakel (1984). Fringing and patch reefs predominate and are restricted to a fairly thin band near shore due to the narrowness of the continental shelf (Hamilton and Brakel, 1984). Patch reefs are often extensions of the fringing reef and arise from the sea floor on most parts of the shelf away from river mouths. Behind the reefs there is a relatively protected lagoon which is extremely important in the productivity of offshore ecosystems (UN/Unesco/UNEP, 1982). The continental islands of Zanzibar, Mafia and Pemba and numerous other small and largely uninhabited islands are surrounded by fringing coral reef (Bwathondi, 1980).

In the north, a series of important reefs lie on the edge of the continental shelf, and are described in the account for Tanga Coral Gardens Reserve. Proceeding southwards, the continental shelf remains narrow until Maziwi Island (*see separate account*), where it broadens to encompass Zanzibar. Charts suggest that extensive reefs (apparently much wider than those off Dar es Salaam) exist on the south-eastern side of Zanzibar, and around Mwemba Island (north-east of Zanzibar) (Howell and Lwiza *in litt.*, 11.10.85). Jones (1969) briefly mentions reefs at Pange and Funga Chawamba, off Zanzibar, with large expanses of undamaged corals. Herring (1972) describes some reef-associated echinoderms off Zanzibar. An early account of the Zanzibar reefs is given by Crossland (1902). South of Zanzibar, the continental shelf narrows in the region of Dar es Salaam where there are several reefs, some of which are described by Hamilton and Brakel (1984) (*see separate account for* "Dar es Salaam Reefs"), as well as the fringing reef on the mainland at Ras Kankadya. Reefs may also occur around Latham Island (Fungu Kisimkasi) (*see separate account*). South of Dar, the continental shelf widens around Mafia Island which lies opposite the Rufiji river and delta (*see separate account*), before the 200 m contour approaches the coast again further south.

Fringing reefs closely adjoining land are generally limited in extent and consist mainly of a reef flat, possibly of an erosional nature, with a limited reef slope. Reefs on islands facing the mainland have more developed reef slopes, extending to a few metres depth, but rarely more than 10 m. Exposed, seaward-facing slopes, both on islands and further out on the shelf, have the most extensive slopes, with fairly regular, gently sloping profiles. About 140 species of corals and a wide diversity of soft corals have been recorded by Hamilton and Brakel (1984). *Acropora* is the dominant genus (Kudoja, 1985).

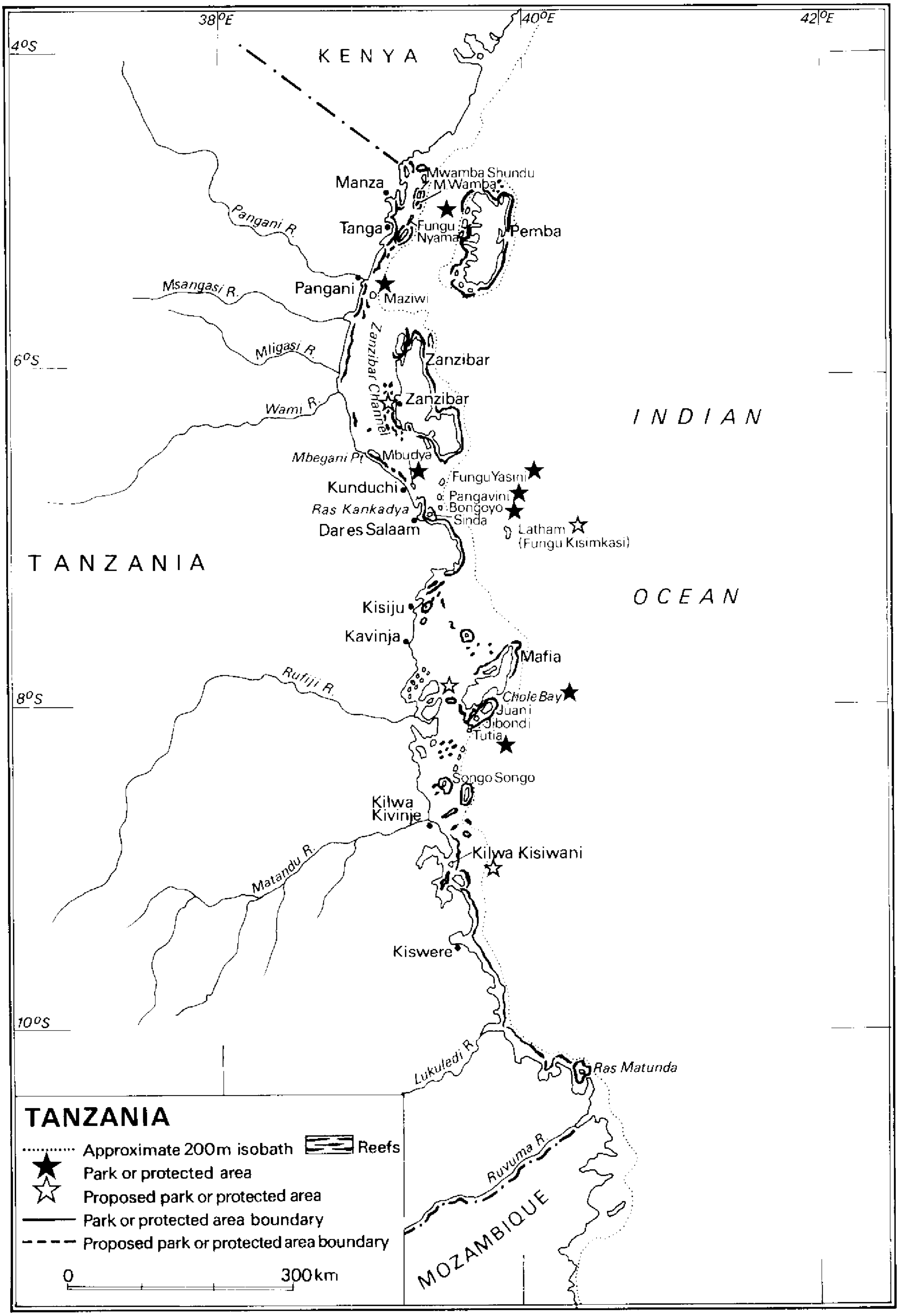
All five species of sea turtle known from the Western Indian Ocean are found in Tanzania. The Green Turtle *Chelonia mydas* has a nesting population of around 300. The Hawksbill Turtle *Eretmochelys imbricata* occurs widely in the abundant reef habitat, although only about 50 nest annually, including perhaps 20 on the main rookery, Maziwi Island. The Olive Ridley *Lepidochelys olivacea* is a rare visitor nesting in small numbers (Groombridge, 1982). Cooper *et al.* (1984) describe the status of breeding seabirds in Tanzania, with special reference to Latham and Mafia Islands (*see separate accounts*).

### Reef Resources

The coast supports less than 10% of the country's population as it is only marginally suitable for agriculture due to unsatisfactory soil types, extreme temperatures and unfavourable seasonal rainfall (UNEP, 1982). The reefs are used widely for fishing, particularly near the coastal towns where fish, shells, lobsters and octopus are taken (Kudoja, 1985). Bwathondi (1980) describes the spiny lobster fishery. Edible molluscs such as clams, mussels and octopus are collected in Zanzibar for home consumption and shells are collected for sale to tourists and for export (Salvadori, 1985). Several of the Tanzanian reefs, particularly in the Dar es Salaam area, are considered important for tourism. Tourism is being developed in Zanzibar and a study of its potential has recently been carried out by the World Tourist Organization and UNDP (Salvadori, 1985).

### Disturbances and Deficiencies

The narrow continental shelf means that the reefs are in close proximity to land and are therefore strongly subjected to terrestrial influences of both natural and human origins (Ray, 1968). Silting of reefs, as a result of inland deforestation, and the use of pesticides may become increasing problems. Sewage and sedimentation derived from dredging and shoreline activities seem to be minor problems at present (IUCN/UNEP, 1982).


38°E
40°E
42°E
4°S
6°S
8°S
10°S
KENYA
Mwamba Shundu
M.Wamba
Manza
Tanga
Fungu Nyama
Pemba
Pangani R.
Pangani
Maziwi
Msangasi R.
Zanzibar Channel
Mligasi R.
Zanzibar
Zanzibar
Wami R.
INDIAN
Mbegani Pt
Mbudya
Kunduchi
Fungu Yasini
Pangavini
Ras Kankadya
Bongoyo
Sinda
Dar es Salaam
Latham
(Fungu Kisimkasi)
TANZANIA
OCEAN
Kisiju
Kavinja
Mafia
Rufiji R.
Chole Bay
Juani
Jibondi
Tutia
Songo Songo
Kilwa Kivinje
Kilwa Kisiwani
Matandu R.
Kiswere
Lukuledi R.
Ras Matunda
Ruvuma R.
MOZAMBIQUE
TANZANIA
Approximate 200m isobath
Reefs
Park or protected area
Proposed park or protected area
Park or protected area boundary
Proposed park or protected area boundary
0
300km

Since the late 1960s, the use of dynamite to stun and kill fish has had serious consequences. Ray (1968) suggests that reefs near Dar es Salaam would be almost completely destroyed within a decade and this prediction has almost come true. Illegal dynamiting has continued, and reef productivity is now so low and the damage so great that fishermen have had to move further afield and there has been a noticeable decline in fish and mollusc yields (Bryceson, 1978 and 1981; Kudoja, 1985). Of the eight reef sites recommended as Marine Parks in 1968, only two (Latham and Mafia Islands) still have intact reefs. The rest have been seriously damaged including some of the finest near Tanga (Kudoja, 1985; Salm, 1983). Trampling of reefs by net fishermen has also caused damage (Ray, 1968). Reef destruction may also have been the cause of the rapid and severe beach erosion along the coast in the Dar area and on Mbudya and Maziwi (Kudoja, 1985) (*see separate accounts*). Groynes have been built on the beaches of the large tourist hotels to halt the erosion but their effectiveness is still being debated (Howell and Lwiza *in litt.*, 11.10.85).

The lack of a modern fishing industry involving Tanzanians was held partly responsible for the reef destruction (Bryceson, 1978) as even in the early 1980s, Tanzanian artisanal fishermen were largely excluded from working in the industrial fisheries. There is now a modern fishing industry (TAFICO) owned by the government, but it has been suggested that coral reefs can, in any case, only support artisanal fisheries (Kudoja *in litt.*, 31.1.86).

The marine curio trade has had a significant impact. Over a quarter of a million kilos of corals and shells were exported in 1974 (IUCN/UNEP, 1982) and reefs around Dar es Salaam in particular became seriously depleted. Increasing pressure from foreign tourists and the demands of overseas markets are beginning to take their toll in Zanzibar (Salvadori, 1985). Green Turtle populations have been reduced by predation, development of nesting beaches and intensive exploitation for food (Frazier, 1976).

**Legislation and Management**

The Ministry of Natural Resources and Tourism administers all natural resources through separate Divisions of Fish, Forests, Tourism and Wildlife (IUCN, 1987). The original Fauna Conservation Ordinance of 1951 was replaced in 1974 by the Wildlife Conservation Act which allows the Government to establish protected areas and sets out how these are to be organised (Kudoja, 1985). Turtles are protected. The following marine areas (*see separate accounts*) were designated in 1981 (Kitomari *in litt.*, 17.3.81; Makumbule *in litt.*, 15.2.82):

- Dar es Salaam reefs:
  - Mbudya Marine Reserve
  - Bongoyo Marine Reserve
  - Pangavini Marine Reserve
  - Fungu Yasini Marine Reserve
- Mafia Island:
  - Chole Bay Marine Reserve
  - Tutia Island Marine Reserve
- Maziwi Island Marine Reserve
- Tanga Coral Gardens Marine Reserve

However, they have never been implemented and appropriate regulations have not been drawn up. Fishing and other human activities, including dynamiting, still take place due to the lack of funds to enforce regulations, light sentences and lack of protection for those enforcing the regulations (Kudoja, 1985; Kudoja *in litt.*, 31.1.86; Msangi, 1985; Mwasaga *in litt.*, 5.10.85). In contrast, Zanzibar has a very active and effective patrol force which strictly prohibits dynamite fishing (Howell and Lwiza *in litt.*, 11.10.85), although no marine protected areas have been established in this area yet.

**Recommendations**

Ray (1968) provided general recommendations for the establishment of a series of Marine Parks and suggested that a Marine Parks headquarters should be established at the Dar es Salaam Marine Park, to cover Park management and education. There is an urgent need to improve enforcement. To help control dynamiting it has been suggested that TNT, which cannot be used by fishermen, should be used as a substitute for dynamite in quarries (Matthes, 1970). The Government has attempted to stop the supply of dynamite and has initiated a publicity campaign but has not been very successful to date (Howell and Lwiza *in litt.*, 11.10.85).

The following additional sites have been recommended for protection:

- Kilwa Kisiwani, for dugong and turtles
- Latham Island, for seabirds (*see separate account*)
- Extension of the Mafia Island Reserves to include the Rufiji Delta and the entire area to become a Biosphere Reserve
- Prison Island (Tortoise Island), about half and hour by boat from Zanzibar town, recommended as a Marine National Park to include the surrounding reef. The island is already a popular recreational site, partly due to the presence there of a group of introduced Aldabra Giant Tortoises (Salvadori, 1985).

Further research is urgently needed and should include the mapping of the reefs. Surveys of the reefs along the mainland and of Zanzibar and Pemba are required, preferably carried out in cooperation with the University of Dar's Institute of Marine Science on Zanzibar and with the local Zanzibar authorities (Howell and Lwiza *in litt.*, 11.10.85). A number of tentative proposals for joint research and monitoring programmes have been made involving the University of Dar es Salaam and a variety of other institutions and agencies such as UNEP, Unesco, UNDP and TANAPA, ODA and the University College of North Wales, Bangor (Howell and Lwiza *in litt.*, 11.10.85; Kudoja *in litt.*, 31.1.86; Mwasaga *in litt.*, 5.10.85). As yet none of these projects are underway.

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## DAR ES SALAAM RESERVES AND REEFS

**Geographical Location** Central Tanzanian coast near Dar es Salaam, centred on 6°50'S, 39°15'E, including Mbudya Island (6°39'S, 39°15'E), Bongoyo Island (6°42'S, 39°16'E), Pangavini Island (6°41'S, 39°14'E) and Fungu Yasini (6°36'S, 39°14'E). The area also includes the inner and outer Sinda Islands and Ras Kankadya.

**Area, Depth, Altitude** Reefs cover 20 km of the coast and extend off shore up to a few kilometres. Mbudya Reef extends to at least 15 m depth on its seaward slope; all others merge with flat, soft substrate at shallower depths. The reserve areas extend to a depth of 9.14 m (5 fathoms).

**Physical Features** Water clarity is reported to be relatively low, due partly to human disturbance (Ray, 1968). Temple (1972) gives a review of the general geomorphology of islands around Dar es Salaam.

**Reef Structure and Corals** Detailed information on the reefs prior to alterations (*see below*) was given in Hamilton (1975) and Hamilton and Brakel (1984). The seaward slope of the reef at Mbudya Island was typical of reefs in this region which are exposed to high wave action. There was a gradual slope of about 30°, without a marked drop-off. No data are available for the turbulent region between 0 and 3 m depth, although three coral zones were distinguished below this. From 3 to 7 m depth, *Acropora* species dominated, notably staghorn forms, *A. palifera, A. humilis* and *A.* cf. *hyacinthus*. Spurs and grooves were also reported, but these were unlikely to be the classic *Porolithon* constructions since they were dominated by *Acropora* spp., and the grooves had appreciable cover by pocilloporid corals. From 7 to 10 m depth, large colonies of *Porites andrewsi* dominated, accompanied by a high diversity of faviids, patches of *Montipora, Galaxea* and several fungiids. *Halimeda* was also common. Below 10 m, large colonies of *Porites* were dominant, and the foliaceous *Turbinaria* and *Pachyseris* occurred at the base of the reef slope.

Reefs at Bongoyo Island were typical sheltered reefs, being more variable in structure and lacking the well-defined coral zonations seen on seaward slopes (Hamilton and Brakel, 1984). On reef flats, acroporids and pocilloporid species were present. On the edge of the reef flat, staghorn and tabulate *Acropora* spp., *Platygyra* and *Galaxea* colonies were predominant. The short reef slope was colonized by foliaceous *Montipora* spp., *Favia* sp. and staghorn corals. At 4 m depth the bottom leveled off and seagrass *Thalassodendron ciliatum* dominated with occasional *Porites* corals. Other species existed, but not in great abundance. The reef slope in south-west Bongoyo showed two distinct zones, one dominated by *A. formosa* and one by *G. clavus*. The former were shallower and supported a higher diversity of other species. *G. clavus* zones tended to be deeper, although the two kinds alternated, and each kind may have dominated over areas of up to 50 m across.

Ras Kankadya Reef was typical of fringing reefs in this region and was very sheltered. The reef flat was probably erosional in origin, the elevated Pleistocene reef being cut down by bioeroders and physical/ chemical processes. Two transects, 100 m and 200 m wide, were studied and were mostly covered by the seagrass *Thalassodendron* but interspersed with coral colonies seawards. Corals were mostly pocilloporids and acroporids, with miscellaneous faviids, *Galaxea* and some *Porites*. At the reef edge there was commonly a luxuriant region of bushy *Acropora*, extending down the reef slope to 1 m depth, where the bottom became a flat, sandy expanse.

The corals of the above reefs appeared to have been representative of the Tanzanian and East African reefs as a whole and numbered about 150 species. The dominance in some areas of species such as *G. clavus*, *P. andrewsi* and *Pavona* sp. was particularly notable.

**Noteworthy Fauna and Flora** *Tridacna* was abundant on the reef flats at Bongoyo Island. Mbudya Island used to be an important turtle nesting site until severe erosion took place (Howell and Lwiza *in litt.*, 11.10.85).

**Scientific Importance and Research** This area is near the Marine Biological Laboratory of the University of Dar es Salaam, and the Fisheries Research and Training Institute of the Ministry of Natural Resources and Tourism (Msangi, 1985).

**Economic Value and Social Benefits** The location of this group of reefs should be of potential importance for residents and visitors to the capital city. There are several hotels along the adjacent shore (Msangi, 1985). Tourism was proposed as a valuable source of income as early as 1968, but damage to the reefs has markedly reduced their value in all respects.

**Disturbance or Deficiencies** There has been severe beach erosion along the coast in the Dar area and on Mbudya Island over a short time, underlining the fragility of the islands and reefs of the area (Howell and Lwiza *in litt.*, 11.10.85). Dynamiting activities are most pronounced in this area and marine curio collection has denuded much of the area near the Capital (Ray, 1968). Coral areas are now reported to be rubble with very few young growing corals (Kudoja *in litt.*, 31.1.86). Mbudya Island has come under heavy pressure from tourism with more than 70 people visiting the island at a time. Many of them collect shells or damage the coral (Howell and Lwiza *in litt.*, 11.10.85). Additional potential threats include pollution from raw sewage that could affect the reefs of Oyster Bay and those from Ras Kankadya to Bongoyo Island (Bryceson *et al.*, 1979).

**Legal Protection** Mbudya, Bongoyo and Pangavini Islands, and Fungu Yasini were designated as Marine Reserves for the protection of assorted fish species and as a tourist attraction in 1981 (Kitomari *in litt.*, 17.3.81; Makambule *in litt.*, 15.2.82).

**Management** There is no actual surveillance of the reefs or islands (Howell and Lwiza *in litt.*, 11.10.85). Government efforts to cut the supply of dynamite and a publicity campaign against dynamite fishing have failed. Previous efforts to protect the reefs have also been unsuccessful. Lack of suitable boats and outboard engines are frequently cited as the main reasons for lack of enforcement (Howell and Lwiza *in litt.*, 11.10.85).

**Recommendations** A permanent patrol with adequate staff and equipment should be established as soon as possible (Howell and Lwiza *in litt.*, 11.10.85).

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## LATHAM ISLAND (FUNGU KISIMKASI)

**Geographical Location** 30 miles (48 km) off shore; 40 miles (64 km) south-east of Dar es Salaam; 6°50'S, 39°50'E.

**Physical Features** Latham is described as Tanzania's nearest approximation to an atoll by virtue of its isolation and deep surrounding waters. It is uninhabited and arises from deep water, outside the continental shelf, and is surrounded by fringing reef. An early description is given by Lane (1944).

**Reef Structure and Corals** No information.

**Noteworthy Fauna and Flora** The current status of seabirds on the island is described by Cooper *et al.* (1984) who list the Masked Booby *Sula dactylatra*, the Greater Crested Tern *Sterna bergii* and the Brown Noddy *Anous stolidus* as regular breeders. Latham Island also supports a large (10 000 to 50 000) colony of Sooty Terns *S. fuscata*. Turtles may occur, probably *Chelonia mydas*.

**Scientific Importance and Research** Latham is the only major seabird island in East Africa (Howell and Lwiza *in litt.*, 11.10.85).

**Economic Value and Social Benefits** The island was once under the control of the Sultan of Zanzibar and was used as a source of fertilizer (guano). Plans for test drilling for oil have been made in the past but so far have not materialized due to lack of funding (Howell and Lwiza *in litt.*, 11.10.85).

**Disturbance or Deficiencies** It is reported to be undisturbed (Salm, 1983).

**Legal Protection** None.

**Management** None.

**Recommendations** The island's rich avifauna and its unique position away from the mainland makes it worthy of study regarding the seabirds, corals and other marine life. It also represents an undisturbed island environment and as such deserves total protection (Howell and Lwiza *in litt.*, 11.10.85).

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## MAFIA ISLAND RESERVES

**Geographical Location** South of Dar es Salaam, opposite the Rufiji Delta, centred at 7°40'S, 39°40'E; including the two reserves of Chole Bay (Chole Island is at 7°59'S, 39°46'E) and Tutia Island (8°7'S, 39°39'E).

**Area, Depth, Altitude** Reserve areas extend to a depth of 9.14 m (5 fathoms).

**Physical Features** Mafia is a continental island, to seaward of the large Rufiji Delta, and has a 20 mi.(33 km) long, unbroken raised reef with an elevation of 3-4 m. Tutia lies to the south and Chole Island to the south-east. Chole Bay lies between Mafia Island, Miawi Island, Chole Island and Juani Island (Mwasaga *in litt.*, 5.10.85). Landward of these the seabed is shallow (maximum depth 50 m) and muddy, due to the influence of the delta. To seaward there are reefs to a depth of about 20 m. Talbot (1965) provided a detailed account of Tutia Reef which is located near the edge of the continental shelf, such that to the south and east the 100 fathom (183 m) contour lies about 2 km out. The area is affected by the north-flowing East Africa Equatorial Current which reaches a velocity of 4 knots when accelerated by the south-east monsoon in May to October, but is slowed to under 2 knots from November to March by the north-east monsoons. The reefs are subjected to 180° reversals of local currents due to tide changes. Salinities are 34.5 ppt, despite the proximity of the Rufiji delta whose turbid outflow misses Tutia. The south-east coast experiences strong waves, but the west and north sides are fairly calm. Cyclones are rare.

**Reef Structure and Corals** The reefs of this region were described as being excellent by Ray (1968) and are still in a relatively undamaged condition (Salm, 1983). The following description comes from Talbot (1965).

The width of the present reef flat on Mafia is up to 800 m. On Tutia Reef, boulder tracts, 80 m wide and projecting 2-3 m above datum, run parallel to the reef edge. The boulders are partly derived from erosion processes as well as from deposition by strong wave action. To seaward of the boulder tracts, is a shallow, algal covered tract, with *Lithothamnion*, but in insufficient quantities to cement the rubble. To landward of the boulders there is a moat with few corals, and further landward on the reef flat, algae dominate.

In the south-east the reef has a gentle slope, without a marked drop-off. A hard limestone reef flat has much *Lithothamnion* and *Turbinaria*, and some corals such as *Acropora corymbosa* and *Porites* boulders. Seaward of this is a spur and groove zone. The spurs are 0.6-1.3 m high and spaced a similar distance apart. Corals increase with distance from the edge of the reef and with depth until, at the lower extent of this zone, coral cover on the tops of the spurs is near total although the groove floors remain scoured. The dominant corals are *A. palifera* and *A. corymbosa*. Below the spurs high coral cover exists on a smoother surface and highest diversity is reached at 8-10 m depth. Beyond 20 m, corals decline and sponges increase. The most conspicuous coral in this region is the very large *P. somaliensis*. In the west, the reef slope is very gradual, supporting few corals and much soft substrate. In the north, there is a near vertical drop-off to 8 m depth which supports *A. hyacinthus* and *A. formosa*. No *Porites* occurs in this region.

**Noteworthy Fauna and Flora** The islands in this region have one third of Tanzania's Green Turtle *Chelonia mydas* population (Ray, 1968). Ras Dima in the Rufiji Delta is an important foraging area for Olive Ridley *Lepidochelys olivacea* (Mwasaga *in litt.*, 5.10.85). Cooper *et al.* (1984) report a breeding population (unknown numbers) of the Roseate Tern *Sterna dougallii*. The neighbouring area of the Rufiji Delta is one of the few places from which the Dugong *Dugong dugon* has been reported (Howell and Lwiza *in litt.*, 11.10.85).

**Scientific Importance and Research** The area is ideal for the study of an integrated system of reef and other marine habitats with brackish and estuarine habitats. A research and monitoring programme is being developed in cooperation with the University of Dar es Salaam, UNEP, Unesco, UNDP and TANAPA (Howell and Lwiza *in litt.*, 11.10.85; Mwasaga *in litt.*, 5.10.85) which will include the Rufiji Delta.

**Economic Value and Social Benefits** There are some tourist facilities but little other use is made of the smaller offshore islands and reefs.

**Disturbance or Deficiencies** These areas have received less disturbance than any others within the continental shelf area (Salm, 1983). However, there are plans to build a large hydroelectric dam at Stiegler's Gorge and it is feared that the resulting environmental changes to the Rufiji Delta could affect the agriculture, mangroves, freshwater and marine fisheries and other related activities of the area. The possible effects on adjacent coral reefs have not been evaluated (Howell and Lwiza *in litt.*, 11.10.85).

**Legal Protection** Chole Bay and Tutia Island were declared Marine Reserves in 1981 (Kitomari *in litt.*, 17.3.81; Makambule *in litt.*, 15.2.82).

**Management** The Ministry of Natural Resources and Tourism manages the Reserve, although regulations have not yet been implemented.

**Recommendations** Ray (1968) recommended a wide area, including several different habitats, for Reserve status. This should include the Rufiji Delta on account of its important dugong population (Howell and Lwiza *in litt.*, 11.10.85). The primary requirement is the establishment of the area as a marine or national park. It is hoped that it will eventually be developed as a biosphere reserve (Mwasaga *in litt.*, 5.10.85).

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## MAZIWI ISLAND MARINE RESERVE

**Geographical Location** Northern Tanzania; 5°30'S, 39°50'E.

**Area, Depth, Altitude** Waters to 5 fathoms (9.14 m) depth; island c. 0.5 ha.

**Physical Features** A low island, well vegetated with bushes and small trees surrounded by coral sand and reef flat. Reported to have submerged in the early 1980s (IUCN/UNEP, 1982; Kudoja *in litt.*, 31.1.86).

**Reef Structure and Corals** No data are available.

**Noteworthy Fauna and Flora** Reported to have been the main Tanzanian nesting site for Green Turtles *Chelonia mydas* and Hawksbills *Eretmochelys imbricata* prior to submergence (Frazier, 1974 and 1976; Mwasaga *in litt.*, 5.10.85).

**Scientific Importance and Research** No information.

**Economic Value and Social Benefits** No information.

**Disturbance or Deficiencies** Frazier (1974) noted rapid beach erosion but no action was taken and the island was washed away in 1982 (IUCN/UNEP, 1982); the causes are not known, but may have included natural events, such as tectonic activity or rising sea-level (Kudoja *in litt.*, 31.1.86), as well as human activities.

**Legal Protection** Declared a Partial Game Reserve for turtles (Frazier, 1976) and a Marine Reserve in 1981 (Kitomari *in litt.*, 17.3.81; Makambule *in litt.*, 15.2.82; Mwsaga *in litt.*, 5.10.85).

**Management** The Ministry of Natural Resources and Tourism manages the Reserve, although regulations have not yet been implemented.

**Recommendations** A proposal for a management programme was drawn up in the 1970s (Frazier, 1974).

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## TANGA CORAL GARDENS MARINE RESERVE

**Geographical Location** North Tanzania, adjacent to Tanga Town; 5°S, 39°30'E.

**Area, Depth, Altitude** A widespread area is involved, covering several reefs.

**Physical Features** Includes the reefs named Mwamba Wamba, Mwamba Shundu and Fungu Nyama.

**Reef Structure and Corals** No information.

**Noteworthy Fauna and Flora** No information.

**Scientific Importance and Research** No information.

**Economic Value and Social Benefits** The reefs are used for fishing (Ray, 1968). Income from tourism is projected.

**Disturbance or Deficiencies** The reefs are close to shore and therefore subject to siltation, pollution from industrial wastes and human pressure. The highest exploitation and destruction by fishermen is taking place at Fungu Nyama due to its proximity to Tanga (11 km). Continuous dynamiting of the reefs and deforestation along the river banks cause erosion and siltation (Mwasaga *in litt.*, 5.10.85).

**Legal Protection** Declared a Marine Reserve in 1981 (Kitomari *in litt.*, 17.3.81; Makambule *in litt.*, 15.2.82); boundaries were worked on by Fisheries Division in 1981 but are still being marked (Mwasaga *in litt.*, 5.10.85).

**Management** The Ministry of Natural Resources and Tourism manages the Reserve, but regulations have not been implemented yet.

**Recommendations** Legislation should be fully implemented and enforced and the reserve should be developed to incorporate the benefits of tourism. It has been suggested that the area could be developed as a biosphere reserve (Mwasaga *in litt.*, 5.10.85). Further information on the scientific interest and importance of the area should be obtained.

# THAILAND

## INTRODUCTION

### General Description

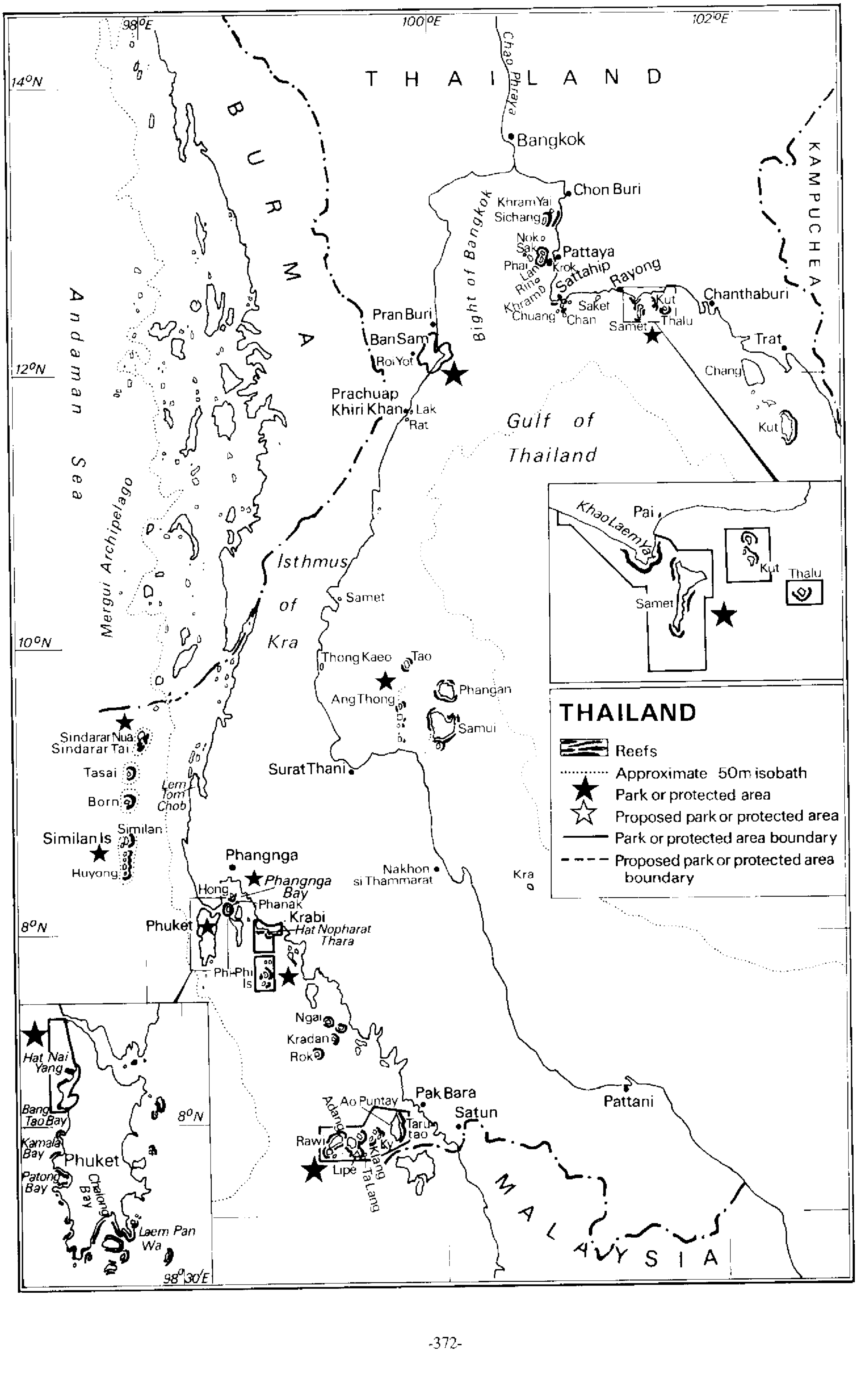
The relatively short west coast of Thailand lies along the Andaman Sea between about 7 and 10°N and has the best developed coral reefs. As on the east coast, these occur around the offshore islands and, due to the influence of the south-west monsoon, are usually located on the east sides of the islands. The west coasts tend to have rocky slopes descending to 10-30 m depth, depending on the location of the island. The southern extension of the Mergui Archipelago lies off the north of this section of coast and is poorly known. Further south, certain islands, such as the Surin Islands (*see account for* Moo Ko Surin National Park), Tasai Island, Born Island, the Similan (or Sayer) Islands (*see account for* Moo Ko Similan National Park) and Rok, lie in deep clear water and have good reefs descending to 25-30 m depth, with coral cover varying according to the exposure of the coastline, and fairly broad reef flats (Kohn, 1971; Sudara, 1981). Islands lying close to the mainland are surrounded by shallow water and include the large island of Ko Phuket (*see separate account*), the Phi Phi (Pipi) Islands (*see account for* Hat Nopharat Thara-Moo Ko Pipi National Park), Ngai and Kradan groups, and the Adang, Rawi and Klang group (*see account for* Tarutao National Park). At Ngai and Kradan Islands there are typical shallow *Porites* reefs extending to 10 m depth with reef flats partially exposed at low tide (Chansang *et al.*, in press). Kohn (1971) described reefs at Pulo Ta Ngah (Tengah, Tenga) (6°34'N, 99°27'E), just north of the border. In a few areas, reefs are found along the mainland coast such as at Phangnga Bay National Park, east of Phuket (*see separate account*). Most of the coast, however, is mangrove-lined (Sudara, 1981). A total of 183 species of coral in 65 genera have been recorded from this coast and the offshore islands (Ditlev, 1976).

The much longer east coast borders the Gulf of Thailand (the northern extension of the Sunda Shelf) from Bangkok (at about 13°N), to about 6°N on the west side and about 10°40'N on the east. Much of the Gulf is shallow (generally less than 60 m and no more than 84 m deep), sedimented and highly productive (Macintosh, 1982; Piyakarnchana, 1981). Most of the mainland coast consists of sandy beaches and rocky headlands with some muddy and mangrove-fringed areas and very few reefs, particularly in the north. Off shore are numerous islands (110 islands off the east coast and 155 off the west coast), which experience clearer water conditions and have areas of soft substrate, hard base rock and reefs to varying degrees. These reefs have lower coral diversity than those on the west coast, and muddy substrate is often encountered at shallow depths (Brinton, 1963; Sudara, 1981).

On the western side of the Gulf there is a small patch of fringing reef on the mainland at Khao Sam Roi Yot National Park, near Pran Buri (*see separate account*). South of Prachuap Khiri Khan (Pracheub Kirikan), there are numerous islands which had extensive coral growth in the recent past, including Ko Samui, Ko Phangan and Ang Tong (*see account for* Moo Ko Ang Thong National Park). The southern part of this coast has few small islands and few coral reefs.

On the eastern side of the northern part of the Gulf, the island of Sichang and numerous small islets support some coral reefs of low diversity, poor growth being due to freshwater run-off from the mainland. The reefs around Sichang have been studied in detail by Chulalongkorn University in the course of work on hermatypic corals (Sakai *et al.*, 1986; Tsuchiya *et al.*, 1986; Yamazato and Yeemin, 1986), marine algae (Kamura and Choonhabandit, 1986a), crustaceans (Nakasone *et al.*, 1986) and fish (Menasveta *et al.*, 1986; Kamura and Choonhabandit, 1986b). The number of islands increases south of Sichang, as does the quantity and quality of their reefs. Several islands occur off Pattaya, such as Ko Nok, Ko Sak, Ko Lan (Ko Larn), Ko Krok, Ko Phai (Pai) and Ko Rin (*see account for* Ko Lan, Ko Sak and Ko Krok). Numerous islands also lie off the naval base at Sattahip (Sataheep) and coral growth is good here, particularly *Acropora* in deep water. Further east, there is some coral growth in rocky areas off the coast of Rayong, and good coral growth on the offshore islands of Ko Saket, Ko Samet, Ko Thalu (Talu), Ko Mun Nai and Ko Man Nok (*see account for* Khao Laem Ya-Moo Ko Samet National Park). East of Rayong, the coastline is largely mangrove-fringed, particularly at Chanthaburi (Chantaburi). There are some offshore islands but corals are not extensive as conditions are not optimal. Off Trat, the town lying near the border with Cambodia, there are again a number of offshore islands with good reef development particularly around the islands furthest off shore (Sudara, 1981).

There are several climatic and oceanic differences between the Andaman Sea and Gulf of Thailand, and a gradient from north to south (Couper, 1983). In general, northern areas show slightly greater seasonal differences in climate, and receive over 3000 mm of rain a year compared with 2000-3000 mm in the south. The southern parts of both coasts, however, experience more thunderstorms per year than the north of the Gulf, and greater variation in winds. The entire region is under the influence of both the north-east and south-west monsoons, the former coinciding with drier weather and the latter bringing heavy rain. On the Andaman coast, the south-west monsoon from May to October causes strong wind and wave action which affects the western shores of islands and the mainland. During the north-east monsoon, from November to April, the sea is calm with periodic strong winds in November and December (Chansang *et al.*, in press). The Gulf of Thailand is more affected by cyclonic weather. Tidal range on both coasts is 2-4 m; tides are semi-diurnal in the Andaman Sea and diurnal in the Gulf of Thailand. Salinities everywhere are below 33 ppt, and are particularly low in the Gulf due to the many rivers which discharge into it (Piyakarnchana, 1981). Surface temperatures are generally 25-30°C. Natural sedimentation is greater in the Gulf due to its shallower, muddy nature, although no part of the western coast on which reefs occur is deeper than about 50 m. Further details of the oceanography and hydrology are given in Hungspreugs (1974), Phasuk (1985) and Robinson (1974).


THAILAND
BURMA
KAMPUCHEA
MALAYSIA
Andaman Sea
Mergui Archipelago
Gulf of Thailand
Bight of Bangkok
Isthmus of Kra
Chao Phraya
Bangkok
Chon Buri
Khram Yai
Sichang
Pattaya
Sattahip
Rayong
Chanthaburi
Trat
Chang
Kut
Samet
Thalu
Pran Buri
Ban Sam
Roi Yot
Prachuap Khiri Khan
Lak Rat
Samet
Thong Kaeo
Tao
Ang Thong
Phangan
Samui
Surat Thani
Nakhon si Thammarat
Kra
Sindarar Nua
Sindarar Tai
Tasai
Born
Similan
Similan Is
Huyong
Lem Tom Chob
Phangnga
Phangnga Bay
Hong
Phanak
Krabi
Hat Nopharat Thara
Phuket
Phi-Phi Is
Ngai
Kradan
Rok
Pak Bara
Satun
Pattani
Ao Puntay
Adang
Rawi
Lipe
Tarutao
Klang
Ta Lang
Pai
Khao Laem Ya
Hat Nai Yang
Bang Tao Bay
Kamala Bay
Patong Bay
Chalong Bay
Laem Pan Wa
98°E
100°E
102°E
14°N
12°N
10°N
8°N
98°30'E
THAILAND
Reefs
Approximate 50m isobath
Park or protected area
Proposed park or protected area
Park or protected area boundary
Proposed park or protected area boundary

Most reef work has been carried out at Ko Phuket in the Andaman Sea by the Phuket Marine Biological Center (*see account for* Hat Nai Yang National Park and Ko Phuket reefs). Fringing reefs in the Andaman Sea are being studied and their status is being assessed especially with regard to dynamite and *Acanthaster planci* destruction (Changsang, 1984; Chansang *in litt.*, March 1985). Long-term monitoring is being carried out at some sites, especially Phuket and the Phi Phi Islands. An inventory of reefs in the Gulf of Thailand is being prepared and a detailed study of the bioerosion of *Porites lutea* is underway at Sichang (Chansang *in litt.*, 6.3.87). A group from Srinakarinvirot University, Bangsan Campus, is studying the reefs around islands off Pattaya, on the eastern side of the Gulf of Thailand. At Chulalongkorn University, Bangkok, the Department of Marine Science is carrying out a general survey of the reefs along this coast in cooperation with the University of the Ryukyus, Japan (Yamazato and Menasveta, 1986). The Brackishwater Division of the Fisheries Department is carrying out work in the Ang Thong (Anthong) Islands (Sudara, 1981). Research on the Gulf reefs is also carried out by Kasetsart University (Monkolprasit, 1981; Sudara and Snidvongs, 1984).

Coral reef fish recorded in Thailand are described in Monkolprasit (1981). Five species of marine turtle occur in Thailand: Green Turtle *Chelonia mydas*; Leatherback *Dermochelys coriacea*, which is rare, but found in waters of peninsular Thailand; Hawksbill *Eretmochelys imbricata*; Loggerhead *Caretta caretta*; and Olive Ridley *Lepidochelys olivacea*, which is the commonest species, occurring all along the west coast and nesting in moderate numbers at a few localities (Bain and Humphrey, 1982; Groombridge, 1982). Nesting beaches in the Gulf of Thailand include Ko Khram (Kram) (in Changwat Chon Buri), Ko Kra (east of Changwat Nakhon Si Thammarat), the Ko Kut/Ko Chang group (in Changwat Trat) and some beaches in Changwat Pattani. Major nesting areas on the west coast are at Phangnga, Phuket, the Similan Islands, the Surin islands and the Adang group (Bain and Humphrey, 1982; Sayer, 1981). Dugong *Dugong dugon* and turtle conservation status is discussed by Piyakarnchana (1985).

**Reef Resources**

Reef-based fisheries for finfish are presumed to be important, especially on the Andaman Sea coast, but details have not been obtained. The fishing industry in the 1970s was reviewed by Aubray and Isarankura (1974). Bhatia (1974) describes the distribution of spiny lobsters on the west coast and the commercial fishery. They are exploited for food and as marine curios and are being studied from the Phuket Marine Biological Center. The reefs are also exploited for the aquarium fish trade and the ornamental shell trade (Lubbock and Polunin, 1975; Piyakarnchana, 1981). Reef-related tourism is becoming increasingly popular, particularly at Phuket which is a major centre for diving tourism. Pattaya on the eastern coast of the Gulf of Thailand is a popular resort (Sudara, 1981).

**Disturbances and Deficiencies**

Piyakarnchana (1981) describes the distribution of *Acanthaster planci* in the Gulf of Thailand. On the eastern coast of the Gulf, reefs were studied at Ko Elau Nok, Ko Rat, Ko Kut, Ko Samet, Ko Chuang, Ko Khram Yai, Ko Rin, Ko Lan, Ko Sak, Ko Phai, Ko Sichang and Ko Kang Kow, and on the western coast, at Ko Lak, Ko Tao, Ko Samet (Samut) and Ko Kra. Detailed studies were carried out at Ko Rin, Ko Kut and Ko Tao. At the end of the 1970s, populations were not considered to constitute a serious outbreak and reef destruction by the starfish was considerably less than that caused by human activities. Reefs in the Andaman Sea were surveyed between 1984 and 1986, following devastation of the reefs at Rok Island and damage on the Phi Phi (Pipi) Islands in 1982 (Chansang *et al.*, in press). They appear to be at different stages of *A. planci* outbreaks. Densities north of Phuket were found to be lower, but significant coral damage was still found at the Surin Islands, Tasai Island (east coast reefs damaged), Similan Islands, Phuket, Phi Phi Islands, Ngai and Kradan Islands, Rok Island and Tarutao. Low tides have been reported to affect coral community structure in Phuket (Brown and Holley, 1981).

Reefs throughout Thailand are severely threatened by overfishing and, in particular, by the use of dynamite and bottom-trawls (Alexander, 1983; Sudara, 1981). In several areas reefs have been completely destroyed, largely due to inadequate law enforcement (Alexander, 1983; Brockelman, 1983). On the Andaman Sea coast, attention has been focused on the Tarutao National Park (*see separate account*) where many reefs have been destroyed by dynamite fishing, but other areas have been affected, such as the reefs around Ngai, Kradan and Rok Islands.

Reefs around islands on the western coast of the Gulf of Thailand such as Ko Samui, Ko Phangan and Ang Thong have been seriously damaged by dynamite fishing and bottom-trawling (Sudara, 1981). Reefs at Ko Chan and Ko Kra were flourishing in 1959 but were largely destroyed by dynamite fishing by 1975 (Piyakarnchana, 1981). On the east coast, poor coral growth in the north around the island of Sichang (Srichang) and adjacent islands is due to freshwater run-off and flooding from land in the rainy season; damage from dynamiting has also been recorded. Illegal dynamiting still occurs around the islands off Pattaya, and there is evidence of bottom-trawling. Further south, the coral community on the rocky shore near the tip of Sattahip is covered with zoanthids and algae due to domestic effluent from villages; however, most of the reefs in this area are healthy. Further east of Sattahip the reefs are deteriorating as a result of sedimentation and coastal erosion from the construction of a deep sea port and breakwater. Reefs off Rayong and around the islands are being damaged in some areas by dynamiting (Sudara, 1981).

The spiny lobster fishery has declined significantly on the Andaman coast, particularly for *Panulirus longipes* and *P. penicillatus* (Bhatia, 1974). Gem-mining near Trat is causing heavy siltation which may affect the reefs around the offshore islands in this area (Sudara, 1981).

In 1980, over 50% of tin production in Thailand came from coastal waters, mostly along the west coast of Phangnga Province on the Andaman Sea. This activity, with the dredging which takes place at the same time, results in high sedimentation loads which has caused noticeable damage, for example in Phuket Bay where tin mining has taken place since 1907. There is considerable conflict between the interests of the tin mining and tourist industries, and the National Environment Board has been carrying out a study to try and resolve some of these issues (Brown and Holley, 1984; Chansang, 1985; Sudara, 1981).

**Legislation and Management**

Traditionally, reefs are public property and anyone may have access to them for fishing and gathering invertebrates (Chansang, 1984). The Fisheries Act B.E. 2490 (1947) and (No. 2) B.E. 2496 (1953), originally drawn up to control inland fisheries, specifies four types of fishing ground and gives the provincial authorities power over their exploitation. It was extended to marine fisheries but has not been entirely satisfactory. Hawksbill, Loggerhead and Green Turtles and dugongs are protected and the use of dynamite and poisons is prohibited. The Act was amended in 1972 to increase penalties for the latter activities. FAO has been assisting the government in a further revision (IUCN/UNEP/FAO, 1978). Legislation prohibiting trawling within three kilometres of the coastline contributes to protection of the reefs. Coral collection is prohibited but action can only be taken if the offender is caught in the act (Chansang, 1984).

Several National Parks, established under the National Parks Act B.E. 2504 (1961), include coral reefs and are described in separate accounts:

Bordering the Andaman Sea:

- Moo Ko Similan National Park
- Moo Ko Surin National Park
- Hat Nai Yang National Park
- Phangnga Bay National Park
- Hat Nopharat Thara-Moo Ko Pipi National Park
- Tarutao National Park

Bordering the Gulf of Thailand:

- Khao Laem Ya-Moo Ko Samet National Park
- Moo Ko Ang Thong National Park
- Khao Sam Roi Yot National Park

Efforts have been made to protect the reefs of Pattaya around the islands of Ko Nok, Ko Sak, Ko Lan, Ko Krok, Ko Pai and Ko Rin in order to promote tourism (Sudara, 1981). The National Parks Division (NPD) within the Silviculture Division of the Royal Forest Department is responsible for the management of National Parks (IUCN, in prep.). General information on protected areas is given in Anon. (1987).

The National Environment Board, established in 1975, has an advisory role and has been involved in the development of conservation policies for the country (IUCN, in prep.; Ludwig, 1976; Sayer, 1981). The National Research Council of Thailand (NRCT) has allocated funds for a number of projects, including a study of water quality in Thai waters and coastal areas (set up in 1973) and a five-year study of coral reefs, initiated in 1982 with Japanese cooperation (Vashrangsi, 1984). Since 1973, 25 stations in the Gulf of Thailand have been monitored for pollution (Hungspreugs, 1984). The Coastal Land Development Project Division was carrying out a survey of coastal development in the 1970s to provide a basis for zoning (IUCN/UNEP/FAO, 1978). A detailed description of legislation relating to the environment is given in IUCN/UNEP/FAO (1978).

**Recommendations**

The National Park Act makes no express provision for marine parks and recommendations have been made that this should be rectified. Recommendations for improved management of the National Parks in general are given in Sayer (1981). Piyakarnchana (1985) makes recommendations for improvements in the legislation relating to marine species. Ko Kra has been recommended as a turtle sanctuary (IUCN/UNEP/FAO, 1978). Bhatia (1974) gives recommendations for improvement of the spiny lobster fishery. General recommendations for improvement of the fishery industry are given in IUCN/UNEP/FAO (1978), including increased patrolling by the Fisheries Department and a reduction in the number of permits issued for trawling. Alternative employment for fishermen could include transportation of tourists and fish farming. Controls should be introduced for the aquarium fish trade and the law controlling coral collection requires revision (Chansang, 1984).

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## HAT NAI YANG NATIONAL PARK AND KO PHUKET REEFS

**Geographical Location** Hat Nai Yang National Park is on the north-west coast of Ko Phuket, adjoining the airport and 32 km from Phuket town. Ko Phuket lies off the west coast in the Andaman Sea; 8°N, 98°20'E.

**Area, Depth, Altitude** Ko Phuket is about 60 km x 30 km, oriented north-south; the 20 m bathymetric contour lies up to 1-2 km from the western coast. The National Park covers 9000 ha including a marine area of 6800 ha.

**Land Tenure** At least one of the central bays (Bang Tao Bay) is leased for mining purposes.

**Physical Features** Ko Phuket, the largest island on the Andaman coast, is separated from the mainland by a narrow channel and is hilly with a very embayed coastline and rocky headlands. The east coast is protected from wind and wave action during both monsoons and is bordered by extensive mudflats and mangroves. The south coast has fairly sheltered bays and some nearshore islands. The west coast is affected by the south-west monsoon and has sandy beaches, with rocky promontories and large bays in the north and rocky areas and small beaches in the south (Chansang *et al.*, 1985). Hat Nai Yang National Park consists of a 13 km strip of coastline, a narrow beach and a coastal hill (335 m) in the south. The marine inshore area includes 3-4 small islands, and largely undisturbed reefs lie 1400 m off the beach. The Park boundary extends 5 km seawards (IUCN, in prep.).

Mean annual rainfall is just over 2200 mm, with most falling in the south-west monsoon (May-October). Mean annual tidal range is 1.8 m but reaches 3.7 m at certain times of the year and tides are semi-diurnal. Currents within 6 km of the western shore are under tidal influence; the oceanic current further out in the Andaman Sea flows south during the north-east monsoon and north during the south-west monsoon (Chansang *et al.*, 1981). The salinity and temperature of nearshore waters are fairly constant (32-33 ppt. and 26-28°C respectively). The prevailing winds are from the north-east, east and south-east during the north-east monsoon and from the north-west, west and south-west during the south-west monsoon. Further details of currents on the west coast are given in Charoenlaph (1982).

**Reef Structure and Corals** Ditlev (1976 and 1978) recorded 183 species of corals from 65 genera from this area, including the smaller islands off Phuket, but at a Unesco workshop (Unesco, 1984b) at least 210 species were listed.

Reefs are found mainly on the south and west coasts and nearshore islands; on the east coast there are a few on the mainland in the south-east but most occur on offshore islands. Chansang *et al.* (1985) distinguish four main reef environments: sheltered bays on the south and south-east coasts; areas on the south-west coast and offshore islands; bays along the north-west coast; and coral communities in exposed areas on the south and west coasts. The best developed reefs are those in the large bay on the west coast. Reefs occur mainly in areas which are sheltered from direct wave action, such as the sides of rocky headlands, and are rarely found on their seaward facing edges or in the bays between headlands (Chansang *et al.*, 1981).

Reef flats examined on the west coast in the vicinity of Bang Tao Bay, Surin Beach and Patong Bay by Chansang *et al.* (1981) support few live corals. Their shoreward sides are covered by coral rubble on a sandy substrate, seaward of which dead coral rocks are found cemented into a dead coral platform. A few corals grow here, notably *Porites, Montipora, Favites* and *Pocillopora damicornis*. *Acropora humilis* is dominant on the dead coral platform close to the reef edge. The best developed reef is the one in Patong Bay. The reef north of Surin Beach, which is more exposed to wave action, shows poor coral development. Reefs on the more protected southern sides of Patong and Bang Tao Bays have more extensive intertidal reef flats and are shallower than reefs on the northern sides. Spur and groove formations are present on the reef edges, although these are smaller than those in many other Indo-Pacific locations, having a maximum groove depth of about 2 m at North Bang Tao Reef. *A. humilis* and *A. hyacinthus* dominate. The reef then generally slopes fairly gently to about 15 m where soft substrate is encountered. The upper slope is dominated by *Acropora* spp. The deeper reef slope has a greater diversity of corals including numerous faviids and mussids. Live coral cover may exceed 50% in places, such as North Patong, but is generally below 40% and is exceeded by the cover of dead coral (Chansang *et al.*, 1981). The reef at Patong (Ao Pa Tong) is briefly described by Kohn (1971), as well as a site on the reef west of the airport. Further details on the reefs of this coast, including those within Hat Nai Yang National Park, are given in Chansang *et al.* (1985).

Reports by Wood and Wood (1982) show that many parts of western Ko Phuket have less than 20% coral cover and are not true reefs but bedrock supporting scattered coral colonies. Several small islets, located a few hundred metres to a few kilometres off shore in the south and south-east, have reefs sloping gently to about 10 m and supporting high coral cover (60-80%). These are interspersed with steeper, deeper areas of bedrock and low coral cover. High soft coral cover was recorded occasionally on the rock slopes, such as at Ko Racha Yai. Brief descriptions of the reefs at Ko Dok Mai, Ko Racha Noi, Ao Kata, Ko Man, Ko Kai Yai, Ko Bon (off Rawai beach) and Ao Sane are also given in the report.

Two basic types of reef were discerned in this area based on the degree of exposure to water movement, one dominated by *Porites lutea* and one by *Montipora ramosa* and *Acropora aspera*. Freshwater runoff, sedimentation and an aerial exposure of 2-3 hours per day may affect the coral populations of these reefs. Brown and Holley (1981, 1982 and 1984) describe coral assemblages of the reef flats around the Laem Phan Wa Peninsula. Ditlev (1978) describes the zonation on the reef flats of the southern coast.

**Noteworthy Fauna and Flora** The Olive Ridley *Lepidochelys olivacea*, is still common at Laem Phan Wa Reserve, and the Leatherback Turtle *Dermochelys coriacea* nests in the National Park; Hawksbill Turtle *Eretmochelys imbricata* and Green Turtle *Chelonia mydas* also occur around the island (Bain and Humphrey, 1982; Groombridge, 1982; Paine, 1987). Dugong *Dugong dugon* used to be present in local waters (Piyakarnchana, 1985). Spiny lobsters *Panulirus* spp. occur around the island (Bhatia, 1974). The fauna and flora of Hat Nai Yang National Park are described in IUCN (in prep.). The Park includes some of the only remaining coastal forest on Phuket and a small area of mangrove.

**Scientific Importance and Research** The reefs of Ko Phuket have been researched in more detail than any others in Thailand and are the best documented due to the presence of the Phuket Marine Laboratory on the Laem Phan Wa Peninsula. The results of numerous studies, several of which included work within the Hat Nai Yang National Park, are published in the Phuket Marine Biological Center Research Bulletin. A survey of living resources along the west coast of Phuket is being carried out with the support of the National Environmental Board of Thailand (Chansang, 1984; Chansang *et al.*, 1981). Studies on coral growth rates and banding have been carried out by Charuchinda and Chansang (1985) and Charuchinda and Hylleberg (1984). A three-year study on the effects of sedimentation on reef corals is under way in collaboration with the U.K. scientists (Brown *in litt.*, Feb. 1985). Two Unesco training workshops have been held at the centre (Unesco, 1984a and b). Turtle rearing and release projects are to be initiated in the Hat Nai Yang National Park (IUCN, in prep.) and a head-starting programme has been under way for twelve years at the Phuket Marine Laboratory.

**Economic Value and Social Benefits** Phuket is one of the main tourist resorts in Thailand. Patong Beach on the west coast is the main tourist area (Chansang *et al.*, 1981) and the reef is popular for diving and snorkelling. Hat Nai Yang National Park has some 20 000 visitors a year, mainly to use the beach (Paine, 1987). Accommodation is being built on the beach and a glass-bottom boat is being purchased (IUCN, in prep.).

**Disturbance or Deficiencies** *Acanthaster planci* became common on the reefs of the west coast in 1983 and coral cover subsequently decreased rapidly in some areas (Chansang *et al.*, in press).

Tin mining has been carried out for about 70 years in the vicinity of Bang Tao Bay. Mine tailings full of sediment are released into canals leading to the bay or discharged directly into the sea. Tin dredges have also been in operation in the bay over an area of about 11.6 sq. km for about six years, causing extensive resuspension of sediment that may be carried as far north as Nai Yang Beach (Chansang, 1985; Nateewathana *et al.*, 1982; Sudara, 1977). There have also been illegal attempts at tin dredging within the Hat Nai Yang National Park (IUCN, in prep.). Wide areas of reef have been smothered, a sediment layer of over 2 cm blanketing the lower parts of the reef. It will take about 30 years to dredge the concession area and there is considerable concern about the long-term effects on the reefs (Chansang *et al.*, 1981). Heavy metal levels have been found to be elevated in reef invertebrates taken from near the Laem Phan Wa Peninsula (Brown and Holley, 1981 and 1982; Brown and Howard, 1985). However, coral cover of reef flats was no lower than that on control reefs further from the smelting and dredging areas, possibly due to the hardy nature of the few reef flat coral species.

Sudara (1981) reports that dynamiting for fish is contributing to the overall deterioration of the reefs in the Phuket area. Tourism may also be having an adverse impact. At Patong Reef there are large areas of dead *Acropora*, possibly caused by tourist boats anchoring within the terrace area which is suitable for snorkelling and diving (Chansang *et al.*, 1981). Overcollection of shells for tourists has been reported (Hunting Technical Services, 1974). The beach in Hat Nai Yang National Park is subject to a turtle egg collecting concession, a proportion of eggs being retained for hatching and release, but it appears that numbers of nesting turtles have declined dramatically in recent years (IUCN, in prep.). A general description of the status of the Phuket reefs is given in Chansang *et al.* (1983).

**Legal Protection** Hat Nai Yang National Park was established 13.7.81 (Anon., 1987); the boundary lies 3 km off shore and includes good reefs (Paine, 1987). In March 1969 an area of 20 sq. km adjacent to the Phuket Marine Biological Center was established as a scientific reserve, under the Fisheries Act; all activities which might disturb the habitat are prohibited (Phasuk, 1985; Chansang *in litt.*, 6.3.87); it is sometimes referred to as the Laem Phan Wa Reserve, and is a turtle nesting site (Groombridge, 1982).

**Management** Dumping of mine tailings has reportedly been stopped and only 2-3 tin mines are now in operation in the area (Chansang *et al.*, 1981). A police station overlooks the bay which has deterred dynamite fishing. Many of the local dive operators do not permit spearfishing or collection of marine organisms by tourists (Wood and Wood, 1982). Hat Nai Yang National Park has a superintendent and about 50 staff (IUCN, in prep.). The headquarters in the north of the park has a visitor centre, administrative buildings and facilities for tourists, but it may not be clear to visitors that they are entering a National Park in other areas (Paine, 1987).

**Recommendations** Chansang *et al.* (1981) recommend a study of coastal sediments in the area between Nai Yang Beach and Bang Tao Bay to examine the long-term impact of tin dredging. The National Environment Board has recently completed a study of the problems created by tin mining in this area and recommendations to alleviate the conflict between this industry and the importance of the area to tourism will be made (Chansang, 1985).

## HAT NOPHARAT THARA-MOO KO PIPI NATIONAL PARK

**Geographical Location** 40 km ESE of Phuket, Krabi Province; 7°46'N, 98°44'E.

**Area, Depth, Altitude** 38 996 ha, of which 32 596 ha are marine.

**Physical Features** The Park includes the two large, predominantly limestone islands of Phi Phi Don (the largest) and Phi Phi Le (spellings as in Chansang *et al.*, in press but equivalent to Pipi), and two smaller islands, the Poh Dah group. They are briefly described by Kohn (1971). Nopharat Thara Beach is adjacent to the estuary of the Klong Hang (Anon., n.d.). Reefs are found in bays and along the eastern sides of the islands (Chansang *et al.*, in press).

**Reef Structure and Corals** Vertical walls descend to 20-30 m depth along most of Phi Phi Le and along the southern part of Phi Phi Don. Those on the east side of the island have 30-40% cover of alcyonaceans, hard corals and sponges (Chansang *et al.*, in press). Further details are given in Unesco (1984b).

**Noteworthy Fauna and Flora** Spiny lobsters were moderately abundant (Bhatia, 1974). Mangroves are present (Anon., 1987).

**Scientific Importance and Research** The reefs were surveyed in the course of a Unesco assessment of coral reef survey methods (Unesco, 1984b). The mainland coast is important for fossil molluscs (Anon., n.d.).

**Economic Value and Social Benefits** The area is important for tourism and is visited by tourists from Phuket (Chansang *et al.*, in press) and Krabi town, from where organised trips can be joined. Phi Phi Le is uninhabited but Phi Phi Don has a fishing village and at least three tourist resorts (Chansang *in litt.*, 6.3.87).

**Disturbance or Deficiencies** *Acanthaster planci* were first reported from the reefs in 1982. In 1986, reefs in the southern bay of Phi Phi Don, which had been in good condition in 1984, were under predation and corals, particularly *Acropora*, on the reef flat and reef slope were dead. In 1984 there was significant damage from dynamiting, particularly outside the bay where the village is located and which is visited by tourists (Chansang, *et al.*, in press). The reefs are reported to be significantly damaged to 8 m depth, the substrate being dominated by soft coral in deeper water (Paine, 1987).

**Legal Protection** Established as a National Park 6.10.83 (Anon., 1987) and opened to the public 14.1.84 (Anon., n.d.).

**Management** Leaflets are available for visitors (Anon., n.d.).

## KHAO LAEM YA-MOO KO SAMET NATIONAL PARK (KO SAMET NATIONAL PARK)

**Geographical Location** Eastern Gulf of Thailand coast; in Changwat Rayong; 12°32'N, 101°31'E.

**Area, Depth, Altitude** 13 100 ha, including a 12 300 ha marine area.

**Land Tenure** Government.

**Physical Features** The park includes a long narrow strip of beach, a rocky headland (Khao Laem Ya), a large island, Ko Samet, and several smaller islands. On the eastern side of Ko Samet there is an extensive and attractive beach, and several of the smaller islands also have good beaches. Average annual rainfall is 1351 mm; annual temperature averages 30°C (IUCN, in prep.). A popular account of the Park is given in Dobias (1982).

**Reef Structure and Corals** The best corals are located off the southern tip of Ko Samet; other reefs can be found near the east and west coasts. Reefs off Ko Kut and Ko Thalu islands are also extensive (IUCN, in prep.; Dobias, 1982).

**Noteworthy Fauna and Flora** Terrestrial fauna and flora are described in IUCN (in prep.). Turtles nested in the past and may still do so infrequently. Black-naped *Sterna sumatrana*, Bridled *S. anaethetus* and possibly Roseate *S. dougalli* Terns nest on some of the islands.

**Scientific Importance and Research** If adequately protected, this will be one of the few unspoilt areas on this coastline.

**Economic Value and Social Benefits** At weekends, up to 200 people visit Ko Samet a day and many also visit the mainland beaches. Boats can be hired from the village of Pai on the eastern boundary, to visit the park. Recreational divers from Bangkok visit the reefs, particularly those that are accessible and those near Wang Kaew where there is good accommodation (IUCN, in prep.).

**Disturbance or Deficiencies** The reefs around Thalu and probably some of the other islands have been damaged by dynamite fishing and boat anchors (Dobias, 1982). The mainland beach has been much disturbed by sand mining, and the mainland vegetation has been largely cleared. There is a major threat from the development of tourism within the park (IUCN, in prep.). The distribution of *Acanthaster planci* was studied on reefs around Ko Samet and Ko Kut in the 1970s; there was no extensive outbreak (Piyakarnchana, 1981).

**Legal Protection** The Park was established 1.10.81 (Anon., 1987).

**Management** There is a small headquarters at Khao Laem Ya, 20 km from Rayong town. It is accessible from the Rayong-Chanthaburi highway. The staff comprises a superintendent, one assistant and 44 casual workers (IUCN in prep.).

**Recommendations** The National Parks Division plans to build bungalows for visitors and to locate the park headquarters on Ko Samet (IUCN, in prep.).

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## KHAO SAM ROI YOT NATIONAL PARK

**Geographical Location** On the western Gulf coast in Prachuap Khiri Khan Province, 37 km from Pran Buri and 250 km south-west of Bangkok; 12°29'N, 100°00'E.

**Area, Depth, Altitude** 9808 ha; max. alt. 605 m.

**Physical Features** The coastal region consists mainly of sand and mud flats, with limestone mountains rising abruptly behind them. There are two offshore islands and a number of small islets. Much of the low-lying land has been drained, and the mangrove stands have been cleared. The water is turbid. Annual rainfall is about 1500 mm, most falling during the south-west monsoon from August to November (IUCN, in prep.).

**Reef Structure and Corals** There is a small area of coral reef in the north of the Park, but no details are available.

**Noteworthy Fauna and Flora** The Irrawaddy Dolphin *Orcaella brevirostris* is frequently found in the turbid waters of the Park. The area is rich in shore birds; turtles and crocodiles used to breed in this area but no longer appear to do so. The vegetation and terrestrial fauna are described in IUCN (in prep.).

**Scientific Importance and Research** The main value of this area currently lies with the terrestrial rather than marine fauna, which is poorly known at present.

**Economic Value and Social Benefits** The Park receives about 2000 visitors a day and up to 200 overnight visitors at any one time, the main attraction being the coastal and wetland fauna and scenery. Two large and prosperous fishing villages are located in the Park (IUCN, in prep.).

**Disturbance or Deficiencies** The fauna and flora of the mountains are fairly well protected due to their relative inaccessibility. The mangroves have apparently been severely reduced, but no data are available on the reefs (IUCN, in prep.).

**Legal Protection** Established 28.6.66 (Anon., 1987).

**Management** There is one superintendent, assisted by one graduate of the Phrae Forestry School, ten permanent guards and 50 casual employees; headquarters and service areas are located to the south of the Park (IUCN, in prep.).

**Recommendations** IUCN (in prep.) provide recommendations for improved management of the park but these do not relate to the reefs.

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## KO LAN, KO SAK AND KO KROK

**Geographical Location** East coast of Northern Gulf of Thailand; 7 km off Pattaya, Chon Buri Province; 12°55'N, 100°47'E. Ko Sak lies 0.5 km to the north of Ko Lan (Ko Larn) and Ko Krok about 2 km to the east.

**Area, Depth, Altitude** Ko Lan is about 7 sq. km; the other two islands are less than 1 sq. km. Depths at the base of the coral reefs extend to at least 14.5 m on the seaward side of Ko Lan but to lesser depths around the smaller islands (Srithunya *et al.*, 1981).

**Physical Features** All localities have waters of varying clarity and low primary productivity. The islands have been described briefly by Srithunya *et al.* (1981) and are typical of many islands in the northern part of the Gulf of Thailand (Sudara, 1981).

**Reef Structure and Corals** Coral reefs fringe most of the shores of all three islands, but are interrupted in places by sandy beaches. Reef flats vary from about 120 to 200 m wide; depths of the reefs vary from very shallow to at least 14.5 m on the west of Ko Lan. About 60 coral species in at least 22 genera have been recorded. The best area for abundance and diversity of corals was on the north-west of Ko Lan (Srithunya *et al.*, 1981). Ludwig (1976) provides estimates of the extent of reef area around each island: 260 000 sq. m at Ko Lan; 1300 sq. m at Ko Krok; and 71 000 sq. m at Ko Sak.

**Noteworthy Fauna and Flora** No information.

**Scientific Importance and Research** The islands are the site of a continuing study by Sri Nakharinwirot University; the site was selected because of its proximity both to the University and to nearby cities which it serves as a recreation centre (Srithunya *et al.*, 1981).

**Economic Value and Social Benefits** The main island of Ko Lan is used as a recreation centre and has several tourist hotels at Laem Hat Non. The coral reefs feature in the tourist trade, and are viewed from glass-bottom boats at Laem Tong Lang where there is a sandy beach. The eastern side of the island is inhabited by several hundred villagers who fish the coastal waters and cultivate the lowland areas (Srithunya *et al.*, 1981).

**Disturbance or Deficiencies** Srithunya *et al.* (1981) state that, although the reefs and corals are relatively undamaged, tourism is heavy in the area, and marine curio collection and pollution are increasing. Illegal dynamiting has taken place and Ludwig (1976) estimated that 20% of the reefs around Ko Lan have been damaged in this way. There are also scars on the seabed from bottom-trawling (Sudara, 1981). In 1973 the reefs at Ko Sak (and neighbouring Ko Rin) were considered to be infested with *Acanthaster* (Piyakarnchana, 1981).

**Legal Protection** None.

**Management** Members of a local diving club carried out a Crown-of-Thorns Starfish eradication programme in 1973 (Piyakarnchana, 1981). Efforts have been made to protect the reefs in this area to promote tourism (Sudara, 1981) but details are not available.

**Recommendations** Srithunya *et al.* (1981) consider that it may be necessary to protect these reefs in the future.

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## MOO KO ANG THONG NATIONAL PARK

**Geographical Location** Off Changwat Surat Thani in the western part of the Gulf of Thailand; 9°56'N, 99°40'E.

**Area, Depth, Altitude** 10 200 ha, of which 8400 ha are marine.

**Physical Features** The park includes a group of small limestone islands, including Ko Thong Kaeo (Kha) and Ko Tao, with beaches and coral flats and their surrounding waters. An inland marine lake is connected to the sea by a cave. Average annual rainfall is 2000 m (IUCN, in prep.).

**Reef Structure and Corals** No information.

**Noteworthy Fauna and Flora** The islands are covered with semi-evergreen and limestone forest. There are relict populations of sea turtles. Some seabirds nest on Ko Thong Kha in the north of the group (IUCN, in prep.).

**Scientific Importance and Research** No information.

**Economic Value and Social Benefits** There is considerable potential for tourism which is already being developed on adjacent Ko Samui, from where daytrips to the National Park are organised. The area is an important spawning and nursery ground for the mackerel *Rastrelliger brachysoma* (Chansang *in litt.*, 6.3.87).

**Disturbance or Deficiencies** The reefs have been damaged by dynamite fishing and bottom trawling (Sudara, 1981). The distribution of *Acanthaster planci* was studied at Ko Tao in the 1970s but the outbreak was not considered serious (Piyakarnchana, 1981).

**Legal Protection** The park was established 12.11.80 (Anon., 1987).

**Management** Not known.

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## MOO KO SIMILAN NATIONAL PARK (SAYER ISLANDS, KO KOW)

**Geographical Location** Andaman Sea, 100 km north of Phuket, 62.5 km from mainland, off Lem Tom Chab (Tam Chok, Cape Dolphin); 8°28'-8°41'N, 97°38'-97°41'E.

**Area, Depth, Altitude** 12 800 ha, including a marine area of 11 400 ha; max. alt. of Ko Similan (Goh Huyong, Great Sayer Island) is 244 m; Ko Paya is 199 m; Ko Miang is 145 m; Ko Payang is 130 m; Ko Huyong (Goh Huyong, South Island) is 170 m. The 100 fathom (183 m) depth contour lies 15 km to the west and is slightly closer in the south but water up to 100-200 fathoms (183-366 m) deep can be found in shore.

**Physical Features** The park includes six small islands and several small islets and wave-washed rocks (Similan, in Malay, and Ko Kow, in Thai, mean nine islands), totalling 3 groups of 9 islands lying on a north-south axis with Ko Similan, the largest, in the north. There are sandy beaches on the north and east of the islands and limited reef flats off some shores. Water is only available intermittently. There is no freshwater on the islands but rainfall is high (IUCN, in prep.).

**Reef Structure and Corals** The reefs are not particularly extensive or spectacular, partly due to the exposure of the area to wave action, and they are less developed than in the Surin Islands. At Ko Huyong, the reef is heavily influenced by wave action. About 55 m from the beach, there is a zone of sparse colonies of *Porites* sp. Beyond 140 m from shore, *Heliopora coerulea* is prominent in some areas and the genera *Acropora, Montipora, Scaphophyllia, Psammocora, Goniopora* and *Goniastrea* are also found. At Ko Similan there are scattered coral heads, mainly of *Porites* but including some *Heliopora*, on the east side, on sand (Kohn, 1971).

**Noteworthy Fauna and Flora** Terrestrial fauna and flora are described in IUCN (in prep.). Marine turtles, including the Leatherback *Dermochelys coriacea* and Olive Ridley *Lepidochelys olivacea*, nest on the islands (Bain and Humphrey, 1982; Sayer, 1981). Little is known of the numbers of different species of turtle but the Similans, through their isolation, may be one of the most important nesting sites. Fish populations are reported to be denser, more diverse and comprise larger individuals than those found in similar habitats elsewhere in the Andaman Sea, possibly due to the close proximity of deep water and to possible local upwelling of cool nutrient-rich waters (IUCN, in prep.).

**Scientific Importance and Research** The islands are visited fairly regularly by staff of the Phuket Marine Center. A Thai-Danish expedition visited the islands in about 1975 (IUCN, in prep.).

**Economic Value and Social Benefits** Molluscs, including Giant Clams, are gathered by sea gypsies. Spiny lobsters are rare (Bhatia, 1974). A navigation beacon is maintained by the Royal Thai Navy on a tower on Ko Similan. Tourism has already started in the area and there is considerable potential for more but this should be on a modest scale (IUCN, in prep.).

**Disturbance or Deficiencies** In the mid 1980s, the *Acanthaster planci* population was low although there was significant coral damage, especially in protected coves on the west coast (Chansang *et al.*, in press). A relatively low intensity of fishing may contribute to the abundance of fish and the reefs are little damaged by dynamite (IUCN, in prep.).

**Legal Protection** The Park was established 1.9.82 (Anon., 1987).

**Management** Not known.

**Recommendations** The islands require a permanent staff with reliable boats and radio equipment, but a major obstacle is the lack of a sheltered anchorage. However, a slipway could be constructed. One of the main objectives of the park is the protection of the nesting turtle population (IUCN, in prep.).

## MOO KO SURIN NATIONAL PARK (KOH SINDARAR OR CHANCE ISLANDS)

**Geographical Location** In the Andaman Sea, about 65 km off the western peninsula, Changwat Phangnga; the northernmost islands in Thailand; 9°16'N; 97°48'E.

**Area, Depth, Altitude** 13 500 ha including surrounding marine area of 10 200 ha; islands reach 1100-1200 ft (335-366 m).

**Physical Features** The park consists of two steep-sided mountainous islands (Goh Sindarar Nua and Goh Sindarar Tai) separated by a shallow, narrow channel. There is freshwater and a sheltered anchorage. Both islands have irregular shorelines with large weathered boulders above the beach and narrow fringing reefs (IUCN, in prep.; Kohn, 1971).

**Reef Structure and Corals** The reefs are described briefly by Kohn (1971). *Porites* is the dominant species but denser and more diverse corals are found along the outer reef margins.

**Noteworthy Fauna and Flora** The fauna and flora of the islands is similar to that of Tarutao and Moo Ko Similan National Parks. The vegetation is decribed by Smitinand (1977), freshwater algae by Buri (1977) and birds by Brockelman and Nadee (1977). Mangroves border the head of the bay on the north-west coast of Goh Sindarar Nua (Kohn, 1971). The islands have a number of nesting beaches for turtles including Hawksbills *Eretmochelys imbricata* and Olive Ridleys *Lepidochelys olivacea* (Bain and Humphrey, 1982; Sayer, 1981).

**Scientific Importance and Research** Considered to be the best developed reefs in Thailand (Chansang, 1984).

**Economic Value and Social Benefits** The islands are uninhabited but are used by tourist. Artisanal fishing has ceased (Chansang *in litt.*, 6.3.87).

**Disturbance or Deficiencies** On east coast reefs, there were some signs of damage from *Acanthaster planci* in the early 1980s, but only a few individuals were seen. *A. planci* aggregations were found on the rocky coast in the south-west. There were extensive dead coral areas along the north and west coasts but no *A. planci* were found (Chansang *et al.*, in press). Dynamiting still occassionally occurs (Chansang *in litt.*, 6.3.87).

**Legal Protection** The Park was established 12.6.81 (Anon., 1987).

**Management** There is a park office, staff quarters and some accomodation for visitors (Chansang *in litt.*, 6.3.87).

**Recommendations** Future development in the area is discussed in Brockelman (1977).

## PHANGNGA BAY (AOW PHANGNGA) NATIONAL PARK

**Geographical Location** Changwat Phangnga, on mainland coast in the Andaman Sea, east of Phuket Island and 9 km from the town of Phangnga; 8°16'N, 98°30'E.

**Area, Depth, Altitude** 40 000 ha of which 34 700 ha are marine. Max. alt. 439 m.

**Physical Features** A shallow coastal area with extensive mangrove swamps and over 40 dramatic limestone islets. In the west there are a number of small islets, some with small beaches and coral flats (IUCN, in prep.). The water is generally rather turbid (Dobias, 1982). A popular description of the park is given in Dobias (1982).

**Reef Structure and Corals** There is coral along the south coast of Ko Hong, the north coast of Ko Nok Khum and the western coast of Ko Phanak (Panak) (Dobias, 1982).

**Noteworthy Fauna and Flora** The area includes some of the most extensive mangrove forest in Thailand and there are small patches of rain forest on the flatter parts of the islands. Dugong *Dugong dugon* occur but are uncommon. Saltwater Crocodiles *Crocodylus porosus* are thought to be extinct in the Park area. Sea turtle nesting beaches are found along the coast in this area (Bain and Humphrey, 1982), but turtle numbers are greatly reduced (Sayer, 1981). The terrestrial fauna and flora is described briefly in IUCN (in prep.).

**Economic Value and Social Benefits** Tourism contributes to the livelihood of many local people, a major attraction being the villages on stilts. Fairly large numbers of visitors arrive by boat from Phuket or via Phangnga. There is a hotel on the eastern boundary of the Park (IUCN, in prep.).

**Disturbance or Deficiencies** Tin dredging used to be carried out here but is no longer an important activity (Brown *in litt.*, Feb. 1985). However, the area still receives mine tailings washed from the coast. Artisanal fishing and mariculture takes place but its impact on the Park is not known (Chansang *in litt.*, 6.3.87).

**Legal Protection** The park was established 29.4.81 (Anon., 1987).

**Management** In 1980, the staff comprized the superintendent and 20 casual workers. The headquarters are near Ban Chap Phrae at the extreme north end of the Park (IUCN, in prep.).

**Recommendations** The park should be zoned and the best mangrove areas strictly protected. There are plans to provide boat excursions for visitors to the park from the headquarters (IUCN, in prep.).

## TARUTAO NATIONAL PARK

**Geographical Location** Andaman Sea, at the extreme south of peninsular Thailand, Changwat Satun; 6°27'-6°46'N, 99°05'-99°46'E.

**Area, Depth, Altitude** Total area 149 000 ha of which 123 000 ha are marine; major islands within the Park are Tarutao (15 100 ha), Adang (3000 ha), Rawi (3100 ha), Lipe (400 ha) and Ko Klang (300 ha); the last four lie about 50 km from Tarutao. These islands are hilly, with Tarutao reaching 721 m. Offshore depths do not exceed about 40 m.

**Physical Features** The Park includes 51 islands and rocky outcrops, which form part of the Sunda Shelf and were separated from the mainland by rising sea-levels about 7000 years ago. Rocks are mostly old hard limestones, granites and sandstones, with some basalt on Rawi. Most of the islands have extensive beaches of fine white sand. Elsewhere the coastline is rocky but some sunken estuaries support mangrove swamps. Sub-littoral areas are mostly sand with some mud and shell deposits and extensive coral flats. A hot spring rises below the high watermark on the north coast of Adang.

Mean annual rainfall is about 2600 mm, possibly slightly lower on the outer islands, falling mostly during the south-west monsoon (May/June until September/October). During this period heavy swells may make navigation difficult. The north-east monsoon (September/October until May/June) causes short sharp seas and occasionally presents access problems to coasts with easterly exposures. Winds tend to be stronger in summer but violent storms, although rare, may occur at any time of the year. The water tends to be turbid (Chansang *et al.*, in press). The mean annual temperature is 27-28°C, being highest in April and coolest in November/December (IUCN, in prep.). Popular descriptions of the Park are given in ASEAN/UNEP (1983) and Dobias (1982).

**Reef Structure and Corals** In the shallow waters between the islands there are extensive areas of "coral gardens", and 69 species of corals and 209 species of molluscs have been identified (WWF, 1983). Both of these numbers are low and are likely to be greatly increased with detailed survey work. More recently, 140 species of coral have been collected from the Adang-Rawi group (Phongsuwan and Chansang, 1986).

There are shallow fringing reefs along the north-east coast of Tarutao and in a bay in the west, 3-6 m deep. The reef flats are exposed at low tide. Low coral coverage was found along the rocky west coast to 5 m depth; higher coverage was found in the large bay on the north-west. On the rocky north-east coast, coral communities are found on vertical walls extending to 7-8 m depth (Chansang *et al.*, in press).

In the Adang-Rawi group, the western coasts are mainly rocky with varying amounts of hard and soft corals. The other coasts are fringed with shallow reefs reaching 15 m depth at some sites. Reefs around Adang, Ta Lang and Rawi have been surveyed in the course of a WWF project (Geater, 1985). Wood and Wood (1983) provide data on four areas, two near Adang (Coconut Grove beach and Ko Ja Bart or Arch Rock), one off Rawi and one off a small islet, Ko Hin Ngam, between the two. These descend gently to less than 10 m deep, and have extensive horizontal areas at 5-10 m which are well-colonized by corals. In some areas, there is non-limestone rock to about 3 m depth. Coral cover varied from 20 to 80%, while soft coral cover was generally less than 20%. Phongsuwan and Chansang (1986) found that reef condition and coral cover was related to degree of exposure to waves and currents.

**Noteworthy Fauna and Flora** The vegetation of the Park is described in IUCN (in prep.) and in detail by Congdon (1982). There are many small areas of mangrove swamp and one particularly extensive and little-disturbed stand near the Park headquarters at Ao Puntay. The Tarutao group has a typical island fauna with few species of terrestrial vertebrates. These and the avifauna are described in IUCN (in prep.). There are no seabird colonies in the Park although the well-documented Booby *Sula* sp. colony of Pulau Perak, in Malaysian waters, lies just to the south. Marine mammals are often reported, but apparently less frequently than in the past. Dugong *Dugong dugon* are occasionally washed ashore or are caught by trawlers. Four species of marine turtle occur: the Pacific Ridley *Lepidochelys olivacea*, nests at low densities; Hawksbill *Eretmochelys imbricata*, which was previously abundant but is now rare, Green Turtle *Chelonia mydas* and Leatherback *Dermochelys coriacea* also occur (Bain and Humphrey, 1982). The main nesting beaches are at Son Bay on Tarutao, Lam Son on Adang, Ky (Egg) Island and on the north coast of Rawi (Ginsberg, 1981). Five species of spiny lobster have been recorded and populations are abundant in some areas (Bhatia, 1974).

**Scientific Importance and Research** A study which included management proposals was produced by a team from the Environment Faculty of Mahidol University led by Dr Naat. Congdon and Ginsberg carried out a study of turtles in 1980-81 (Ginsberg, 1981; WWF, 1983). A WWF/IUCN project was initiated in 1982 to gather basic information on the condition and composition of coral reefs within the National Park in order to formulate a feasible management and protection plan, and to encourage co-operation between staff and students of Prince of Songkhla University, which now has an Underwater Research Group, and staff of Tarutao National Park in scientifically sound field research (Geater, 1983; Geater *in litt.*, 5.10.85). Particular attention is being paid to the reefs of the Adang group (Geater, 1985). The marine fauna has been studied by the staff of the Marine Biology Centre at Phuket. Further research is to be carried out on the impact of *Acanthaster planci*, dynamiting and rates of reef recovery (Geater *in litt.*, 5.10.85).

**Economic Value and Social Benefits** Until 1947 Tarutao was the site of a prison and several buildings were constructed at Tala Oudang and Tala Wao in the south, linked by road. Numerous artifacts remain on the islands from this period. Several large villages existed on Tarutao until the 1970s, but the only persons living there now are National Parks Division employees and their families. A small resident population was forcibly evicted from Ko Klang in 1976. The outer islands (Adang-Rawi group) are inhabited by sea gypsies (Chao Lay), most of whom live in a village on Lipe (population 700), with a few families on Adang and Rawi. The authorities have provided a school on Lipe (IUCN, in prep.). Reef resources of the Adang and Rawi islands are described in Phongsuwan and Chansang (1986). The Chao Lay traditionally live by inshore fishing, mostly for molluscs including *Tridacna* (IUCN, in prep); there is some spiny lobster fishing (Bhatia, 1974).

Tourism is being developed. Fishing boats can be hired from Pak Bara or Satun to Tarutao. Lodging for about 200 guests is available at Park Headquarters in the form of bungalows and bamboo buildings. Camping areas are also provided, along with a medical station, a library and a small store. Boat trips can be made to the reef and a film and slide show is presented at the museum in the evenings. The National Parks Office in Bangkok or Tarutao Park Office should be given prior notice of visits (IUCN, in prep.).

**Disturbance or Deficiencies** No *Acanthaster planci* were found on Tarutao in the period 1984-1986, but populations were found on Klang and in the Adang-Rawi group. Reefs on Adang were damaged but those on the east and south coasts of Rawi were still in good condition (Chansang *et al.*, in press; Phongsuwan and Chansang, 1986). Geater (1985) found large numbers of starfish around Ko Ta Lang, and considerable dead coral, but no starfish on Adang and only a low density on Rawi.

The reefs of the Park are among the most severely damaged of all in Thailand as a result of dynamite fishing and bottom-trawling. Large areas are still being destroyed, especially by blasting (Alexander, 1983). Extensive areas have now been turned into beds of loose rubble. During the WWF/IUCN project, high percentage coral death was found on reefs to the north of Adang and on the east of Rawi (Geater, 1985). Damaged reefs, possibly due to dynamiting, were found on Klang in 1986 (Chansang *et al.*, in press; Phongsuwan and Chansang, 1986) and blasting caused damage at a site on Ta Lang in 1985, where reef recovery is now being monitored (Geater, 1985). The pressures by fishing interests are such that the 3 km fishing limit which applies throughout Thailand has been reduced to only 1 km in this Marine Park. This limit is frequently ignored with the result that trawl damage is becoming common close to the islands.

Turtle populations have been adversely affected by the dynamite fishing, but it is thought that this group of islands is one of the few areas in Thailand where, with adequate protection of both the adults and the nesting beaches, large populations could be restored. Disturbances to the terrestrial part of the Park are described by IUCN (in prep.).

**Legal Protection** The group of islands was declared a National Park 19.4.74 (Anon., 1987) and has been designated a Heritage Park under the ASEAN Heritage Parks and Reserves scheme (ASEAN/UNEP, 1983).

**Management** The Park Headquarters at Ao Puntay on Tarutao Island have staff and visitor accommodation, offices, electricity generator and radio contact with the NPD in Bangkok. In 1981 the staff consisted of a graduate superintendent, two assistants, who are graduates of Phrae Forestry School, 11 permanent guards and 132 casual employees. There is an information centre at the Headquarters with an aquarium containing examples of the local marine life as well as introductory leaflets. The reefs at Talo-Ayang Bay on Sadang Island and those surrounding Hin Ngaru Island have been demarcated as recommended snorkelling areas for visitors; other reefs are to be reserved for research work only. There are three marked nature trails on Tarutao. A marine turtle conservation programme was initiated in 1983 (WWF, 1983) and WWF/IUCN have assisted with the Park since 1981. There is a system of fines for people caught collecting shells, corals or plants. Infringements in the form of illegal dynamite fishing and bottom trawling have been too numerous for the small Park staff to handle and armed battles between Park staff and "pirates" have caused deaths and injuries on both sides.

**Recommendations** It may be necessary to enlist assistance from the navy or police to help the Park authorities with enforcement. Plans are being made to establish a regular monitoring programme for the reefs, using students from Prince of Songkhla University. It may be necessary to implement control measures for the Crown-of-Thorns Starfish if there are further signs of damage (Geater, 1985). Additional recommendations are given in Phongsuwan and Chansang (1986).

# UNITED ARAB EMIRATES

## INTRODUCTION

### General Description

The United Arab Emirates extend from the Qatar Peninsula to Oman, along about 450 km of the Gulf coast. A further 100 km of coast faces the Gulf of Oman immediately south of the Musandam Peninsula, which is part of Oman. The Gulf coast is low-lying with extensive tidal flats, lagoonal areas and sand dunes (Sheppard, pers. obs., 1975; Shinn, 1976). The water is very shallow and therefore subject to extremes of temperature, including very low temperatures caused by Shamals (northerly cold fronts) in winter which exert severe constraints on coral growth. Numerous offshore islands and banks provide marginally more favourable conditions for coral reefs (Kinsman, 1964; Shinn, 1976). The predominant current flows eastwards from the Qatar Peninsula. The coastal area bordering the Gulf of Oman is more mountainous. In the north, it consists primarily of sandy beaches with rocky headlands. The latter diminish towards the south as the coastal strip becomes low-lying with lagoonal areas. A general description of the coastal environment is given in Carp (1976).

Along the Gulf coast, although the water is very shallow for many kilometres off shore, coral reefs occur as patch reefs and submerged banks over broad areas (Kinsman, 1964; IUCN/UNEP, 1985; Shinn, 1976). They are formed primarily from *Acropora* of a branching to tabular form, and also from large colonies of *Porites* and some faviids. Rosen (1971) records 14 genera from the Trucial coast. No detailed surveys have been carried out on these reefs. No true reefs have been found on the Gulf of Oman coast which appears to have a largely sandy sublittoral. However, a wide range of coral species were found to at least 6 m depth, providing coral cover of less than 3%, on a centrally located rocky headland near the large town of Khawr Fakkan (Sheppard, pers. obs., 1985).

The status of breeding colonies of seabirds in the United Arab Emirates is described by Gallagher *et al.* (1984). The islands of Qarnayn and Zarka have large populations (at least 10 000 birds each) of the Socotra Cormorant *Phalacrocorax nigrogularis*. Other species nesting in the region include up to five species of tern *Sterna* spp., the Red-billed Tropicbird *Phaethon aethereus* and the Sooty Gull *Larus hemprichii*. Marine molluscs are described in Smythe (1979). The island of Dayyinah has nesting populations of Hawksbill Turtles *Eretmochelys imbricata* (Ross and Barwani, 1981). Green Turtles *Chelonia mydas* probably nest but no data are available. Near the southern border there is an extensive mangrove stand at Khawral al Kalba which extends into Oman.

### Reef Resources

Some limited recreational diving occurs off the headland near Khawr Fakkan and off a small island just off shore (Sheppard *in litt.*, 1986). Fisheries in the UAE are described by Morgan (1985); Lethrinidae, Serranidae and Lutjanidae comprise the major portion of the demersal catch.

### Disturbances and Deficiencies

No information.

### Legislation and Management

Environmental departments within the Abu Dhabi National Oil Company assist with environmental impact assessments (IUCN/UNEP, 1985).

### Recommendations

A number of coastal areas have been recommended for protection (Carp, 1976) but these probably do not include reefs.

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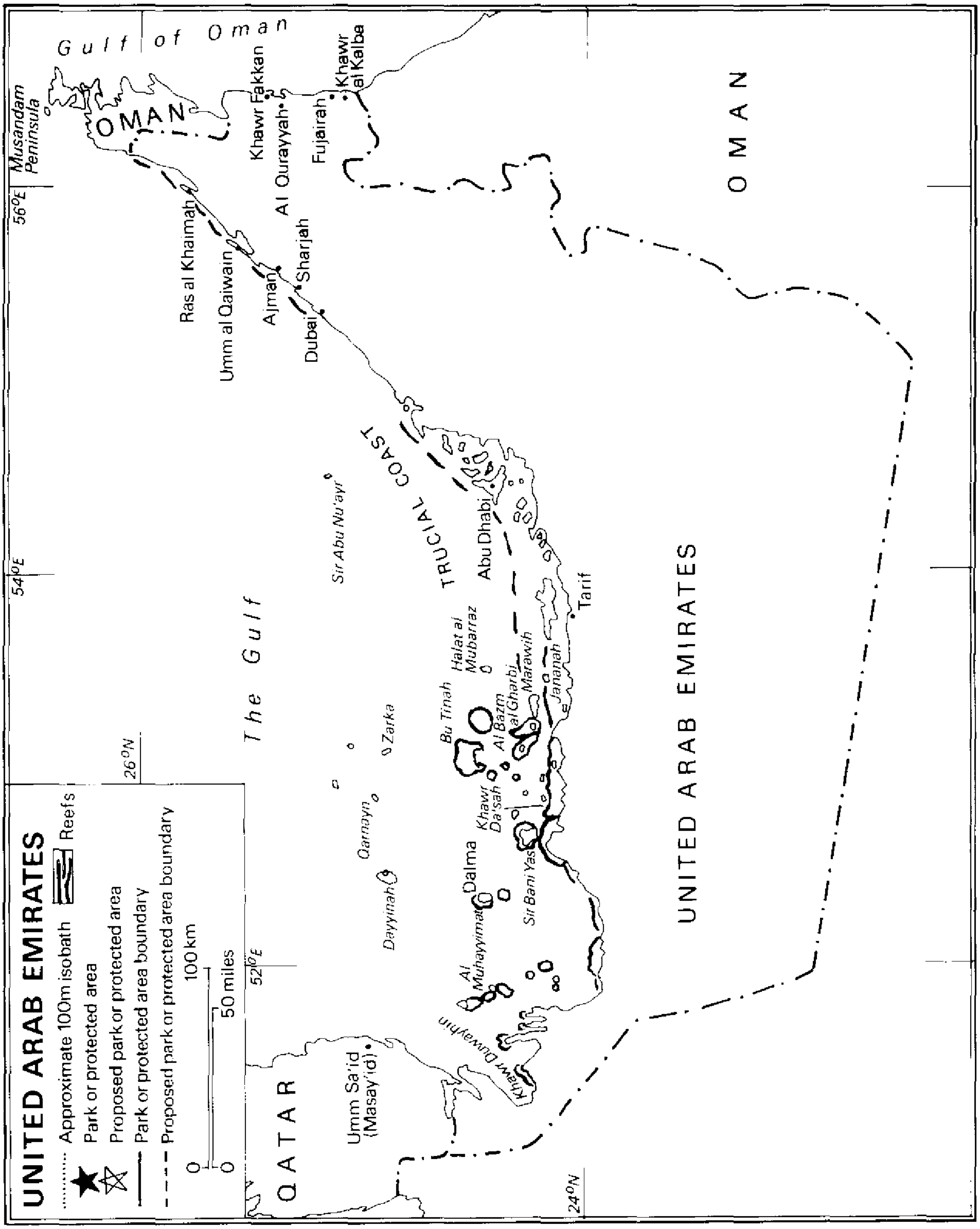
UNITED ARAB EMIRATES
Approximate 100m isobath
Reefs
Park or protected area
Proposed park or protected area
Park or protected area boundary
Proposed park or protected area boundary
0 100 km
0 50 miles
QATAR
Umm Sa'id (Masay'id)
52°E
54°E
56°E
26°N
24°N
The Gulf
Gulf of Oman
OMAN
Musandam Peninsula
Ras al Khaimah
Umm al Qaiwain
Ajman
Sharjah
Dubai
Al Qurayyah
Khawr Fakkan
Fujairah
Khawr al Kalba
TRUCIAL COAST
Abu Dhabi
Tarif
Sir Abu Nu'ayr
Halat al Mubarraz
Bu Tinah
Al Bazm al Gharbi
Marawih
Jananah
Zarka
Qarnayn
Dayyinah
Dalma
Khawr Da'sah
Sir Bani Yas
Al Muhayyimat
Khawr Duwayhin
UNITED ARAB EMIRATES
OMAN

# OTHER COUNTRIES

## BANGLADESH

A general description of the marine environment of Bangladesh is given in UNEP (1986a). The only known coral reef in Bangladesh occurs around St Martin's Island (20°37'N, 92°18'E), an island of about 6 sq. km, in the Bay of Bengal, 13 km from the south-east mainland coast and 95 km south of Cox's Bazaar. It is reputed to be a submerged reef but scientific knowledge of the area is still very limited. The island is inhabited by about 3000 people, most of whom are fishermen. Parts of the reef are said to be completely destroyed due to shell and coral collection, but it is possible that domestic and industrial effluents, dynamite fishing and recreational pressure have added to the problem (Fattah, 1979). Scientific expeditions to the island took place in 1973 and 1979 (UNEP, 1986a). St Martin's Island is being surveyed as a potential marine park as it is also an important wintering ground for wildfowl and a nesting site for marine turtles (Khan, 1985; UNEP, in prep.).

## BRUNEI

Owing to the somewhat turbid nature of Brunei's coastal waters and its sedimentary and mangrove-fringed coastline, coral formations are few and of limited extent. According to reports from the Fisheries Department and the Royal Brunei Armed Forces there are small reefs close to Pulau Punyut and the Pelong Rocks, but species diversity is poor. Potentially the most interesting site is the Louisa Reef, about 230 km off the coast and lying within Brunei's EEZ. However, none of the coral formations in Brunei have been scientifically studied although several are occasionally visited by SCUBA divers at weekends (Chua *in litt.*, 29.1.87; Farmer *in litt.*, 18.6.87; Phillips *in litt.*, 28.2.87). Three marine wildlife sanctuaries have been recommended for establishment (Farmer *in litt.*, 18.6.87):

- Louisa Reef: a coral reef system fringing the top of an oceanic sea mount with depths of at least 1600 m nearby.
- Pelong Rocks: protection of the 2 ha area of outcrops recommended primarily for nesting seabirds, in line with proposals by the Brunei Museum; an area of at least 500 m around the Rocks should also be included to protect associated marine life and coral formations.
- Pulau Punyut: protection of the 8 ha islet and adjacent headland recommended primarily for nesting seabirds, in line with proposals by the Brunei Museum; an area of at least 500 m around this should also be included to protected the associated marine life.

## KAMPUCHEA

Reefs may occur around some of the coastal islands (Morgan and Valencia, 1985) but no data are available.

## PAKISTAN

Coral reefs are not at present known from Pakistan (UNEP, 1986b). However, Qureshi (1961) describes the seabed on the Makran or Baluchistan coast as being muddy but with patches of coral and rocks in some areas. It is suggested that this coast would be more suitable for coral growth than the Sind coast as it has harder substrates and less turbid water. It is thought that further research may reveal more extensive coral communities, for example Astolla Island, near Pasni, and Ormara (UNEP, 1986b).

## SOUTH YEMEN

There is little information on the reefs of South Yemen. The Arabian Sea coast is thought to be similar to that of Oman and probably has some reef areas interspersed with algal dominated communities. The South-east Arabian upwelling directly influences the coastal area in the vicinity of the South Yemen/Oman border (IUCN/UNEP, 1985).

Scheer (1971) visited Abd El Kuri (12°10'N, 52°15'E), an island between Socotra and Ra's Asir (Cape Guardafui) which is surrounded by steep slopes unsuitable for reef development. Scattered corals (9 genera) were found and macrophytic algae predominated (Scheer, 1964). The coast of Socotra was visited in 1984 by members of the Laboratory of Microplankton of the Southern Branch of the Institute of Oceanology, Academy of Sciences, USSR, who studied various aspects of phytoplankton over the reefs (Sorokin, 1985). The islands of Ukban and Kamaran come under the jurisdiction of South Yemen, but lie to the north in the Red Sea, off the coast of North Yemen. They are partly surrounded by coral reefs and are referred to in the section on North Yemen. The geology of Kamaran is described by Macfadyen (1930) and coastal sediments in this area are being studied by El Anbaawy (1984).

A Marine Science and Resources Research Centre was established by the government in 1983 with the assistance of Unesco and the Islamic Development Bank, but research activities will concentrate on mariculture and the assessment and monitoring of marine pollution (IUCN/UNEP, 1985). Oil exploration is taking place off the northern coast and there is potential for pollution.

Laws exist concerning the marine environment, coastal zone and fishing. The discharge of oil, ballast, rubbish and other harmful substances into the marine environment is prohibited. Law No. 24 of 1979 prohibits the use of toxic, explosive or chemical substances for the purpose of fishing. Law No. 13 of 1976 established the National Environment Council which has responsibility for the open sea and advises on environmental matters. Responsibility for the conservation of nature, wildlife and genetic resources lies with the Ministry of Culture and Tourism (UNEP, 1980). The Ministry of Fish Wealth will be involved in the development of marine research and conservation activities.

Ghadaf and Stirn (1983) have made preliminary recommendations for protected areas:

- Ra's Abu Quizara - a peninsula surrounded by rocky shores with hard bottom submarine communities and coral assemblages.
- Perim I. - "transient" coral fields and hard bottom communities around the island and the lagoon of Ghuraira; reported Hawksbill Turtle *Eretmochelys imbricata* nesting site (Hirth and Carr, 1970; Hirth and Hollingsworth, 1973).
- Socotra I. - part of the terrestrial and marine environment to be protected.
- Nishtun - eastern marine environments in this area to be protected.

## VIETNAM

Reefs occur around several of the offshore islands but are sparse on the mainland (Morgan and Valencia, 1983); reefs around the Con Son Islands off the southern tip of Vietnam are considered to be particularly rich (Vo Quy, pers. comm., 1988). Reefs in the Namsu and Thu Islands and off Hon Yom Cape were visited by members of the Laboratory of Microplankton of the Southern Branch of the Institute of Oceanology of the Academy of Sciences, USSR, during the cruise of the r/v Acad. Nesmeyanov in 1984. Studies on plankton nutrition, the metabolism of Alcyonaria and the release of organic matter by corals were carried out (Sorokin, 1985). Reefs in the Xisha Qundao (Paracel Shoals) are described in the section on China in Volume 3.

Reef fisheries are considered to be relatively unexploited. The National Conservation Strategy currently being developed (Anon., 1985) will take into consideration the need for marine conservation. A marine park is being developed around the Con Son Islands (Vo Quy, pers. comm., 1988).

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