6
Coral and Biogenic Reef Habitats

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Opposite page: A soft coral of the genus *Scleronephthya*, found occasionally under ledges and overhangs on reefs in the WIO. © Michael H. Schleyer.

INTRODUCTION

Coral reefs are among the best-known marine habitats in the WIO. They are found throughout the region where rocky substrata occur between about 0 and 50 m depth, and water clarity and quality are adequate to give them a competitive edge through their symbiosis with zooxanthellae living within their tissues. The distribution of coral reefs in the WIO is relatively well known, comprising four main classes of reef: fringing reefs are found around all the islands and along the East African coast; barrier reefs are most strongly developed at Tulear (Madagascar) and around Mayotte (which also has a second/inner barrier within its lagoon); atolls are found in the Seychelles (eg Aldabra, Cosmoledo, Farquhar, Alphonse) and Mozambique Channel (Europa, Bassas da India and the submerged atolls of Zélée and Geyser); and numerous coral banks, such as those along the continental coastline (eg at Malindi, Kenya; Leven and Castor, NW Madagascar; Africa Bank, Mozambique), and the very large oceanic banks of the Mascarene Plateau (Cargados Cajaros, Nazareth and Saya de Malha), and the North Seychelles Bank.

The precise area of reef habitat in the WIO is not yet determined accurately. The most commonly used area estimates (Table 6.1) include many 'coral reef-associated' habitats, such as deeper rubble beds and channels between reefs. The Millennium Coral Reef Mapping Project, which has completed the most comprehensive global mapping of coral reefs has validated maps for the islands, giving higher reef areas in many cases than previously thought (see Table 6.1), but the mainland reefs have not been validated. Because the fringing reef systems of the mainland coast are generally narrow and have high levels of terrestrial input, light penetration is generally low, introducing significant errors in analysis of satellite images.

Non-coral biogenic reefs are limited in distribution in the WIO, though many facies of coral reef environments are dominated by other biota that build reef frameworks (as mentioned above), including coralline algae, seagrasses, foraminifera, pelycepods and others. In temperate waters, bivalve reefs become more common, particularly in South Africa in intertidal and shallow subtidal zones (Beck and others, 2011); further work will probably reveal some in the southern temperate waters of Madagascar as well (Bouchet 2012).

Because coral reefs are among the most biodiverse and productive ecosystems, and are found in benign environments along the coast, they support many human activities, and are among the most valuable of ecosystems for the services they provide. Thus, they are of great importance for both intrinsic and utilitarian reasons. They have been exhaustively covered in prior regional syntheses, for example the national level Marine Ecosystem Diagnostic Analyses (MEDA) and regional Trans-boundary Diagnostic Analyses (TDA) conducted by the TRANSMAP, WIOLAB, ASCLME and SWIOFP GEF projects (see TRANSMAP 2008, UNEP/Nairobi Convention Secretariat 2009, ASCLME/SWIOFP 2012a, ASCLME/SWIOFP 2012b).

Table 6.1. Summary of coral reef statistics for countries and major reef areas in the WIO. Adapted from Obura and others (2012).

	Reefs at risk[a] %	Reef area km² [b]	Coral diversity [c]	MPAs with coral reefs [d]
Comoros	99	430/305	314/223	1 (1)
Iles Eparses	na	na/121		1
Kenya	91	630	237/240	10
Madagascar	87	2 230/5 076	315/293	13
Mauritius	81	870/2693	215/185	21
Mayotte (Iles Eparses)	100/na	570/413 (121)	216/274 (40/209)	2 (6)
Mozambique	76	1 860	314/297	6[c]
Reunion	100	<50	168/205	1
Seychelles	17	1 690/5 443	310/217	14
Somalia	95	710	308/na	0
South Africa	na	50	na/91	2
Tanzania	99	3 580	314/280	11

Notes:

a- Reefs at Risk country estimates reported in Spalding and others, 2001. Country estimates were not given in Reefs at Risk revisited, in 2011.
b- Reef areas were obtained from the World Atlas of Coral reefs, and for the islands (to the right of the '/') from the Millennium Reef Mapping project. Differences in these numbers reflect different methodologies and assumptions about reef habitats and structure.
c- The first numbers are from two sources: mainland sites- Spalding and others, 2001 (World Atlas of Coral Reefs) based on Veron (2000) estimates of predicted numbers of species; island sites - based on field surveys and literature for RAMP-COI. The second number is the predicted species richness based on field surveys (Obura 2012) and are probably underestimates of true diversity. Discrepancies between these numbers are based on differences in methods and sources of information.
d- Numbers of marine protected areas with coral reefs in Madagascar and Mozambique have increased greatly since the source report was published, these numbers incorporate estimated increases. Mayotte/Iles Éparses : two EEZ MPAs and, in Mayotte, six restricted-use MPAs.

SCALE OF BIOLOGICAL DIVERSITY (MAIN GRADIENTS OF DIVERSITY FOR SPECIES AND COMMUNITIES)

The Western Indian Ocean is recognised as a distinct biogeographic region (Longhurst 1998). In the Marine Ecoregions of the World (MEOW) classification (Spalding and others, 2007), it is placed in the West Indo-Pacific Realm that stretches from the Andaman Sea westwards over the entire Indian Ocean. On the basis of hard coral species, Obura (2012) proposed adjustments to the MEOW classification to more closely match the Regional Seas definition of the WIO (including the whole coast of Somalia up to the Horn of Africa), but also adding the Chagos Archipelago, reflecting its role as a stepping stone in east-west connectivity across the Indian Ocean (see Sheppard and others, 2012).

Though a number of major global initiatives have surveyed species diversity in the Indian Ocean, eg the Challenger expedition, the International Indian Ocean Expedition in 1950-60 and, most recently, in the Census of Marine Life, it is recognised that the WIO has been poorly sampled compared to other regions, with large gaps in the numbers of species reported in even major taxa (Griffiths 2005, Wafar and others, 2011). Overall, some 2000 species of reef fish and just under 400 hard coral species have been reported for the WIO (Veron 2000, IUCN 2013, Obura 2012). Historically, species diversity across the Indo-Pacific region has been seen as one of linear decline in all directions from the high-diversity centre in the south-east Asian region, or Coral Triangle (Veron and others, 2009, Roberts and others, 2002). This paradigm showed decreasing diversity of reef taxa as far as the African coast with, in some cases, a peak of diversity in the Red Sea and/or the Seychelles islands (Sheppard 1987), attributed to endemism.

However, this is being re-evaluated as recent studies show an increase in diversity of reef taxa westwards from the Indian Ocean islands to the African coast, peaking in the northern part of the Mozambique Channel (Reaka 2008, Tittensor and others, 2010, Obura 2012). Drivers for this pattern include tectonic/paleo-oceanographic drivers over the course of the Cenozoic (Obura 2015), as well as Quarternary influence of the South Equatorial Current (SEC) and Mozambique Channel eddies accumulating and maintaining species in the northern Mozambique Channel (Tsang and others, 2012, Obura 2012). Consequently, the northern Mozambique Channel may be a second peak of shallow marine biodiversity in the world, after the Coral Triangle.

From here, there is decreasing diversity north and south as currents flow out of the northern Mozambique Channel, with transitions towards the north and south due to mixing with other water masses and climatic regions. In northern Kenya, Somalia and the northern Seychelles islands, there is a faunistic transition to species characteristic of the extreme environments and habitats of the Gulf of Aden and Persian Gulf, and endemism already noted for the Red Sea (Randall 1998). In southern Madagascar and southern Mozambique, there is a transition to the temperate systems of the Madagascar Plateau, South Africa and the southern Indian Ocean, resulting in high levels of endemism in southern Madagascar in fish and invertebrates (Bouchet 2012), and shared species between southern Madagascar and South Africa.

Endemism in the Mascarene Islands (Mauritius, Reunion and Rodrigues) is high, being isolated from the more biodiverse areas, being south of the main flow of the SEC. The level of endemism of reef fish in the Mascarene Islands is fifth highest globally, comparable to levels reported for the remote island groups of the east part of the Pacific, such as the Hawaiian Islands, the Galapagos and Easter/Pitcairn Islands (Randall 1998). There are 37 species endemic to these islands out of a total of 819 species associated with them. Endemism in the northern Seychelles islands is somewhat lower, due to exchanges with northern parts of the Indian Ocean. In corals, ten per cent of the species found in the WIO are endemic to the W & N Indian Ocean (ie From Sri Lanka and S India westwards), with the balance (90 per cent) being widespread in the broader Indo-Pacific (Obura 2012), a proportion also reflected in the fish.

An increasing number of genetic studies are now being conducted in the WIO, with a bias towards fish due to their commercial importance. Results from fish emphasize the uniqueness of the Mascarene Island fauna due to high endemicity in the remote islands (Hoareau and others, 2013, Postaire and others, 2014), and genetic exchange between the Indian and Atlantic oceans with fluctuating currents around the coast of South Africa (Teske and others, 2011). Based on phylogenetic origins of coral species, the WIO is hypothesised to be a 'museum' for species that originated in the Tethys Sea some 30-50 mya and have not dispersed west to the Central Indo-Pacific (Obura 2015). This is in contrast to the majority of species, most of which have more recent origins in the Southeast Asian region and have dispersed into the WIO in ocean currents.

PROPORTION OF MAJOR GROUPS OF SPECIES THAT ARE ASSESSED ON A SYSTEMATIC BASIS FOR STATUS

Coral reefs have been a strong focus of research, with better representation of major coral reef taxonomic groups (eg hard corals, reef fish, epibenthic molluscs, echinoderms and others) in faunal inventories compared to, for example, soft substrata or deep sea habitats (Griffiths 2005, Wafar and others, 2011). Even so, problems in taxonomic assessments remain even in well-studied groups such as corals and fish. Reef fish and hard coral (Sheppard 1987, Obura 2012) diversity have been assessed comprehensively at the regional level, building on multiple national or sub-regional studies (eg, for corals: Rosen 1971, Pichon 1978, Schleyer and Celliers 2003, Riegl 1996). Other groups have been assessed on sub-regional scales, eg hydroids (Gravier-Bonnet and Bourmaud 2006), and others, with a focus on commercial species, eg sea cucumbers (Conand and Muthiga 2011). Taxonomic information on hard and soft corals, mangroves, seagrasses, holothurians and crabs is compiled in a six-volume CD set produced in the early 2000s.

Marine megafauna that range widely beyond coral reefs are often recorded on them, partly due to the presence of scientists/observers in reef systems: eg turtles, seabirds (Birdlife International 2012, Le Corre and Jaquemet 2005), marine mammals (Ridoux and others, 2010), and whale sharks (Rowat 2007) (and see Chapter 9 on deep sea and offshore habitats, and summaries in Obura and others, 2012). Broad public interest in these groups enables citizen observation networks to provide useful biogeographic and status information on the species, eg marine mammal sighting networks in a number of countries, the Indian Ocean-South East Asian (IOSEA) network for sea turtles, Birdlife International for seabirds, etc. The lack of biodiversity data for the WIO region in global databases (eg the Ocean Biogeograhic Information System (OBIS) and Global Biodiversity Information Facility (GBIF)) is notable and far more severe than for other regions, resulting in inaccurate comparative results.

WIO countries need to invest in biodiversity assessments and data archiving to fill the above gaps, but it is essential that adequate standards are maintained to provide input to global resources such as OBIS/GBIF, as well as regional ones, such as the Africa Marine Atlas (ODINAFRICA). There even are problems with the hard coral and fish datasets which have insufficient location data and poor identifications from one study to another. A further problem is that corals are presently undergoing major taxonomic revision; traditional taxonomy has proven to be a poor match to true phylogenetic relationships, as corals have undergone considerable convergence in their macroscopic characters which are used in traditional taxonomy. This is only now being revealed by new genetic and microstructural techniques (see Budd and Stolarski 2011). As a result, much of the historical genus-level work, which is adequate for ecological purposes, will need to be completely revised for any conclusions on biodiversity and biogeographic patterns.

The application of molecular techniques such as genetic barcoding is therefore urgently needed. While this may be technically challenging and expensive, it does enable studies in the region to 'leap-frog' to faster data capture using new methods. Genetic techniques also assist in aligning regional work with global taxonomic references and standards. Finally, high levels of diversity in microbial and invertebrate communities are undescribed (Mora and others, 2011), and genetic and genomic techniques could yield significant advances in marine science if applied in the WIO.

As an ecosystem, coral reefs have thus been broadly assessed in the WIO, capacity having been developed for national monitoring systems in the late 1990s and early 2000s under the umbrellas of the Global Coral Reef Monitoring Network (GCRMN), the Nairobi Convention and the Indian Ocean Commission, as well as in numerous national and bilateral programmes. Information from the region has been compiled in global (Wilkinson 2000) and regional reports (CORDIO 2011), as well as analytical assessments of reef status and drivers (McClanahan and others, 2007; Maina and others, 2008; Ateweberhan and others, 2011).

TRENDS AND THREATS

Drivers

Coral reefs are valued for their ecosystem services, and are thus subjected to significant use and threats throughout the WIO. The exploitation of marine resources (particularly fisheries), urban pollution, terrigenous sedimentation, coastal development and tourism are among the main anthropogenic pressures that cause degradation of coral reef ecosystems in the region. These are strongly driven by population growth and economic development where regulation of impacts is weak (UNEP/Nairobi Convention Secretariat , 2009, ASCLME/SWIOFP 2012a, ASCLME/SWIOFP 2012b).

Pressures, state and impacts

Fishing pressure is increasing globally with population growth, and globalization of fisheries is resulting in mounting pressures on even remote mid-ocean reefs and banks. Destructive fishing with small-mesh seine nets, poison and dynamite are pervasive where national governance mechanisms fail to keep them under control. Migrant fishing is increasing in intensity, driven by degradation of local systems, causing fishers to travel farther afield.

Threats from pollution are less severe in the WIO than elsewhere, reflecting the low levels of industrialization and maritime trade by world standards, though these are increasing. One third of all global oil tanker traffic passes through the Mozambique Channel (GEF-WIOMHD 2012), prompting efforts to establish a marine highway and contain pollution risks, though regulations have not yet been approved. Coral diseases are on the rise globally with the increase in the human footprint and are of concern in the WIO, though levels are apparently low except at localities subjected to high anthropogenic influence.

Similarly, pests such as crown of thorns starfish (*Acanthaster planci*) occur in small 'outbreak' populations, mainly in mainland countries and Madagascar, generally on limited and isolated patch reefs a few kilometres in extent. These go through 5-10 year cycles from outbreak to recovery, often close to freshwater and terrestrial influence that may promote their boom and bust cycles. One hundred and four introduced or alien species and 45 cryptogenic species have been identified in multiple marine habitats within the region, but only five are considered to be invasive. Perhaps the most damaging is the blue mussel, *Crassostrea gigas*, which is invasive in bays and harbours in temperate and sub-tropical climes in South Africa. Surveys for invasive species on coral reefs have not yielded significant threats.

Climate change is now recognized as one of the greatest threats to coral reefs worldwide, particularly from rising sea surface temperatures and ocean acidification. Coral bleaching has led to substantial damage to coral reefs on a global scale (16 per cent of reefs suffered lasting damage in 1998 alone: Wilkinson 2000), with some parts of the western Indian Ocean losing 50-90 per cent of their coral cover (eg Kenya, Tanzania, Seychelles, Mayotte) in the major bleaching event of 1998, associated with an El Niño and Indian Ocean Dipole event. Since then, minor bleaching events have been reported in numerous localities, particularly in 2005 and 2010, but none as extensive as the 1998 event. Regional studies of coral bleaching have revealed different histories of bleaching, indicating high- and low-vulnerability regions to potential future climate change (McClanahan and others, 2014). Reefs in hot stable temperature regimes in the east of the Mozambique Channel and the Seychelles, and in cooler but more variable regions in Kenya, have apparently suffered greater bleaching, but reporting is scanty from many representative sites. Reefs in cooler conditions at the southern edge of the WIO distribution of corals have not suffered from coral bleaching, with hard coral cover increasing slightly over the last 15 years (Schleyer and Celliers 2003), perhaps benefiting from warming conditions. For the Indian Ocean as a whole, 65 per cent of reefs are at risk from local and global threats, rising to >85 per cent by 2030 (Burke and others, 2011). The threat of ocean acidification to coral reefs in the WIO is currently unknown, though researchers in South Africa and Reunion are beginning to tackle this issue.

The growing global energy demand has led to increased exploration for oil and gas within the WIO (Kenya, Tanzania, Mozambique, Madagascar and Seychelles). Tanzania has been a natural gas producer for many years, from the Songosongo and Mtwara regions, and recent natural gas finds in Cabo Delgado, northern Mozambique, are the largest global finds in 20 years, constituting some 30-65 Tcf (trillion cubic feet) of recoverable gas resources. There is a high likelihood of similar finds elsewhere, particularly in the Mozambique Channel, which will probably transform the economies of these East African coastal states. Whether this occurs in a framework of sustainability with minimised damage to the environment, or with no regard for environmental standards, will determine the future of the region profoundly. Over and above continuously increasing local threats (eg fishing) and threats from climate change, extraction of fossil fuel reserves may pose the most significant threat to reefs and other nearshore ecosystems by virtue of the transformation and growth it will cause in all economic sectors.

A vivid example of the combined effects of these stresses is the Grand Récif at Tulear – the largest barrier reef in the Indian Ocean, and earlier recognized as an exceptional reef system for its diversity, complexity and size. However, in the last 40 years, combined pressures from local threats (small scale commercial fishing, urban pollution and massive sedimentation), compounded by climate drivers, have resulted in widespread degradation of the reef system (Bruggemann and others, 2012), with the loss not only of ecosystem function, but also of many species, including reef-building corals.

The emergence of remote sensing techniques and information technology for amassing and managing large and global datasets have enabled the development of integrated threat assessments for coral reefs (Halpern and others, 2009, Burke and others, 2011) that will aid future management of coral reefs. However, the indices vary in their estimate of threat levels, eg Reefs at Risk predicts high risks for most of the coral reef coastlines on the African mainland and Madagascar (Figure 6.1, left), but Maina and others (2011) anticipate medium threats for most of these locations (Figure 6.1, right).

Responses

Coral reefs have been the focus of marine management in the WIO region due to their high biodiversity, and initially for their importance for tourism. In the past, as fishing was considered the greatest threat, protection of reefs was prioritised to shelter some locations from fishing pressure for their conservation. However, with mounting evidence of the importance of protected zones to maintain and replenish fisheries (Partnership for Interdisciplinary Studies of Coastal Oceans 2007), reef management is now recognized as a key tool in fisheries management.

Among the main tools for reef management, area-based tools such as Marine Protected Areas (MPAs) include a range of protection levels, involving the partial or full protection of certain resources from use or extraction in no-take zones. The WIO has been a leader in marine conservation, having some of the first marine protected areas globally (Inhaca Island in Mozambique, and Malindi and Watamu Marine Parks in Kenya, in the 1960s) and two World Heritage marine sites, Aldabara and iSimangaliso, making coral reefs among the best-represented habitats on the World Heritage list and in the WIO (Obura and others, 2012).

Other tools for management include temporal tools, such as area closures during certain seasons or critical events (such as spawning events), and effort and extraction controls such as on numbers of fishers and types/methods of fishing allowed. Historically, coral reef management in the WIO was driven by central government agencies. Fish-

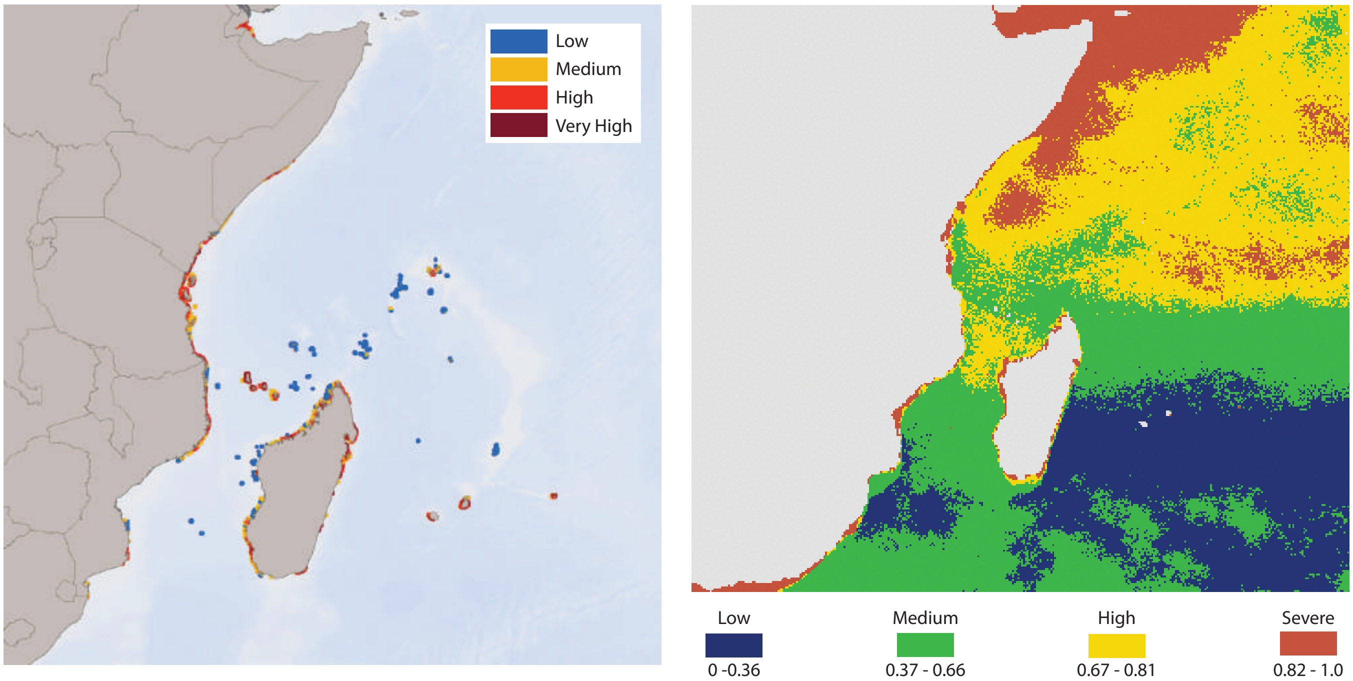

Figure 6.1. Maps of integrated threats to WIO reefs, from left: Reefs at Risk (Burke and others, 2011), and right: Maina and others, (2011).

ing communities are now increasingly realising the value of taking on the responsibility and authority to limit access to reefs on which they depend, in Locally Managed Marine Areas (LMMAs) (Rocliffe and others, 2014). These initiatives are typically undertaken in co-management arrangements with central government, usually under the authority of Fisheries rather than Conservation legislation.

Restoration of degraded reef communities has not yet reached a level where action can be taken at ecological scales (Edwards 2010), though successful piloting of reef restoration through coral nursery and transplantation are being undertaken at Cousin Island, Seychelles, and in Tanzania. Restoring the conditions that promote natural recovery – adequate herbivore and consumer populations, a clean environment and connectivity corridors – can be accomplished in well-planned MPAs or through fisheries and coastal management at a larger scale than can be achieved by attempts to manipulate local reefs through replanting of corals.

Three broad areas of intervention are possible to manage coral reefs sustainably (Table 6.2). These are particularly important in WIO countries where large sectors of the coastal populations are poor, and rely directly on the ecosystem goods and services from reefs for their economic security. While biodiversity conservation is an essential tool to maintain ecosystem services, the broader goals of societal sustainability and welfare are needed in the WIO to justify allocation of resources to coral reef management.

A holistic and broad-based approach will be needed to manage the entire seascape or EEZs of WIO countries (Sale and others, 2014) to ensure sustainable coastal ecosystems into the future.

At the regional level, a Coral Reef Task Force has the role of coordinating work under the Nairobi Convention,

Figure 6.2. Distribution of Marine Protected Areas and Locally Managed Marine Areas in the Western Indian Ocean (from Rocliffe and others, 2014).

including reporting to the GCRMN, while the Indian Ocean Commission has developed a database/information system to support coral reef monitoring throughout the WIO region through its various projects (most recently the ISLANDS project, and in 2014-2017 under the 'Biodiversity Project') (ISLANDS 2013).

WIO countries have all signed the Convention on Biological Diversity, and have thus adopted Targets set under the Convention to effectively manage ten per cent of their marine zones by 2020. Currently, MPAs are estimated to cover some 130 000 km^2 in the region (Rocliffe and others, 2014), representing some two per cent of the EEZs in these countries within the Western Indian Ocean province; a sizeable gap remains before the Aichi Target 11 is attained by 2020. The French islands, with their low human population density and dependence on the marine environment

Table 6.2. Classes of action that can be taken to manage coral reefs. Source: Sale and others (2014).

Build resilience to enable recovery following impacts		
Natural threat	i. Catastrophic geologic: earthquake, tsunami, volcano, meteors	The WIO has very low risk from these, being a tectonically passive region.
	ii. Meteorological and climatic: tropical storms, floods, droughts.	Severe storms smash coral reefs or bury them under sediment. The Mascarene Islands, Madagascar and Mozambique are vulnerable to cyclones.
	iii. Extreme low tides	Not a threat in the WIO due to macro-tidal range.
Global change threats	i. Elevated sea surface temperatures	Coral bleaching in corals may be temporary or lethal; it stimulates algal blooms on reefs, increases disease.
	ii. Increased storms, wider climatic fluctuations	Stronger storms will smash or bury coral reefs; increased rain increases sediment fluxes.
	iii. Rising CO_2 dissolved in seawater with increasing ocean acidification	Decreases calcification in corals and other organisms; higher CO_2 may increase algal productivity.
	iv. Diseases, plagues and invasive species	Intensity and frequency correlated with environmental change.
Direct conservation measures possible using area-based, temporal and other tools		
Direct human pressures	i. Exploitation: over-fishing, dynamite fishing and trawler damage (exacerbated by population growth, global markets)	Harvesting of fishes and invertebrates beyond sustainable yields, includes damaging fishing practices (dynamite, cyanide fishing); boat scour and anchor damage to reefs.
	ii. Sedimentation increase: farming, logging, development	Excess sediment on coral reefs caused by poor land use, deforestation and dredging; reduces photosynthesis; associated with disease.
	iii. Nutrient and chemical pollution.	From untreated sewage, agriculture, animal husbandry and industry wastes; includes complex organic substances, heavy metals, inorganic chemicals. Eutrophication reduces light penetration, promotes growth of competing algae on corals. Chemicals kill various species associated with coral reefs.
	iv. Development of coastal areas	Removal or burial of coral reefs for urban, industrial, transport and tourism development; mining reef rock and sand beyond sustainable limits; coastal hardening results in erosion.
	v. Hydrocarbon extraction and spills, maritime pollution	Localized impacts from extraction and shipping infrastructure; increased risk of oil spills and other chemical pollution.
Improved policy and legislation reduce impacts and enable conservation measures		
Governance, awareness, will	i. Rising poverty, increasing populations, alienation from land	Impoverished, dispossessed people increase extraction of reef resources for subsistence and habitation; tragedy of the commons.
	ii. Poor management capacity and lack of resources	Few trained personnel for coastal management, raised awareness, enforcement and monitoring needed; lack of funds and logistics for management.
	iii. Poor political will, low priority for oceans governance	Political ignorance, indifference, inertia; corruption and low transparency in governance at national and regional levels impede decision-making and reduce resources.
	iv. Uncoordinated global and regional conservation arrangements	Poor coordination among Multilateral Environmental Agreements and international donors results in overlapping meetings and reporting requirements, exhausts capacity in smaller countries.

(except Mayotte, which is densely populated) have recently designated their entire EEZs as MPAs, contributing greatly to the total (Mayotte: 70 000 km^2 and Glorieuses 48 000 km^2). Seychelles has committed to conservation-based management of 30 per cent of its EEZ under a 'debt for climate adaptation' swap within a Trust Fund that it is establishing.

Most of the other countries have very high levels of subsistence dependence on coral reefs, low government resources for protection and management, and high pressures for development. The rate at which they can better manage their coral reefs and other marine habitats will probably be slow. However, a number of regional initiatives will contribute to the required targets, including upscaling the LMMAs in all countries under a regional network. Both Madagascar and the Comoros made Presidential commitments to expand their marine protected areas in number and coverage at the World Parks Congress in November 2014 in Sydney Australia, providing significant impetus to up-scale efforts in the coming decades.

Monitoring data suitable to assess the performance of countries in meeting their obligations to multiple Millennium Ecosystem Assessments is essential (Pereira and others, 2013), and coral reefs are among the few marine ecosystems for which this should be possible - they are one of the ten environments for which globally-consistent sources of marine data are available (IODE workshop, Townsville November 2013). Innovative assessment tools such as global threat assessments (Halpern and others, 2009, Burke and others, 2011) and the Ocean Health Index (Halpern and others, 2012) could also assist countries in meeting these reporting requirements.

Greater recognition of the ecosystem services contributed by coral reefs (to communities, global tourism, economies and trade) would provide impetus to secure resources to monitor the ecosystem processes and indicators that underpin these goods and services, incentivizing monitoring and assessment to manage them for future benefit. The IPBES and the Sustainable Development Goals should, in parallel with the CBD, generate increased justification to upscale coral reef assessments globally.

CONCLUSION

Coral reefs are among the Western Indian Ocean's most biodiverse and valuable ecosystems, and are probably the most vulnerable and threatened. The principal drivers of impacts – population growth, demographic migration to coasts, urban and coastal development, and climate change – all deleteriously affect reefs. WIO countries have a track record of reef research and management and conservation of their reefs but, with ongoing growth in all drivers within the region, as well as at global levels (Secretariat of the Convention on Biological Diversity 2014), a paradigm shift in commitment to limit impacts will be needed. The justification for such increased commitment is high, given the economic and social value of coral reefs and the irreplaceability of some of their ecosystem services. The recent commitment by the Comoros and Madagascar to increase protection of their marine environment shows what is possible. This will require the involvement of state and non-state, thereby assuring the survival of coral reefs into the future for the well-being of those who depend on them.

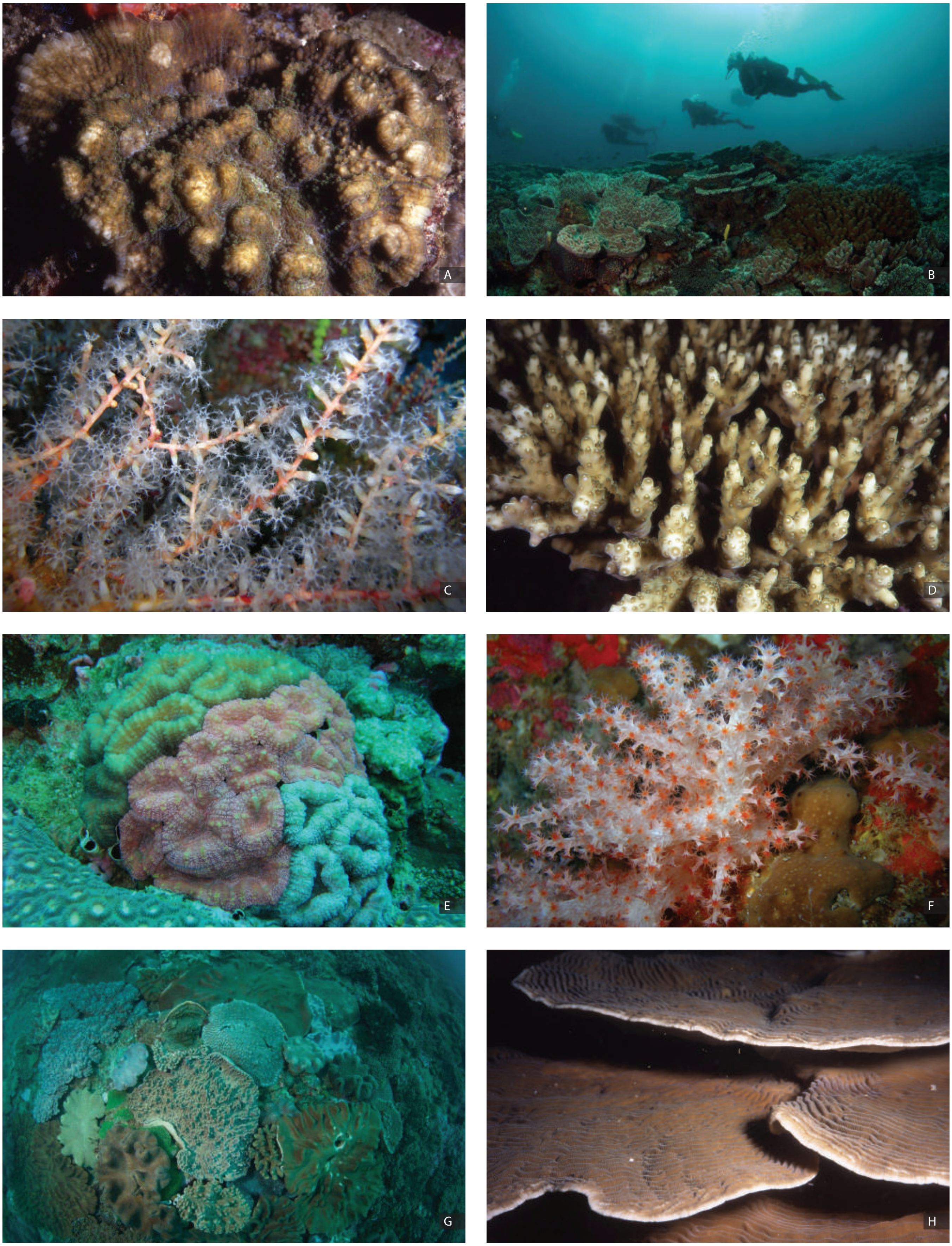

Figure 6.3. Corals are extremely variable: An encrusting hard coral (*Echinopora*) **(a)**; divers moving over a reef vista **(b)**; a branching soft coral (*Carijoa*) **(c)**; a digitate staghorn (*Acropora*) coral **(d)**; a lobate coral (*Lobophyllia*) **(e)**; a spiny soft coral (*Stereonephthya*) **(f)**; mixed hard and soft corals **(g)**; and a plate coral (*Pachyseris*) **(h).** © J Tamelander (b, g) and Michael H. Schleyer (a, c-f, h).

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