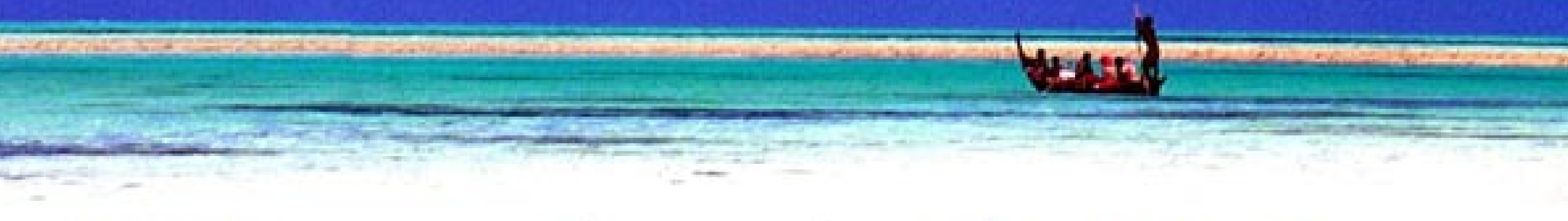
VITAL COAST GRAPHICS

OUR PRECIOUS COASTS

MARINE POLLUTION, CLIMATE CHANGE AND THE RESILIENCE OF COASTAL ECOSYSTEMS

RAPID RESPONSE ASSESSMENT



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Christian Nellemann and
Emily Corcoran (Editors)

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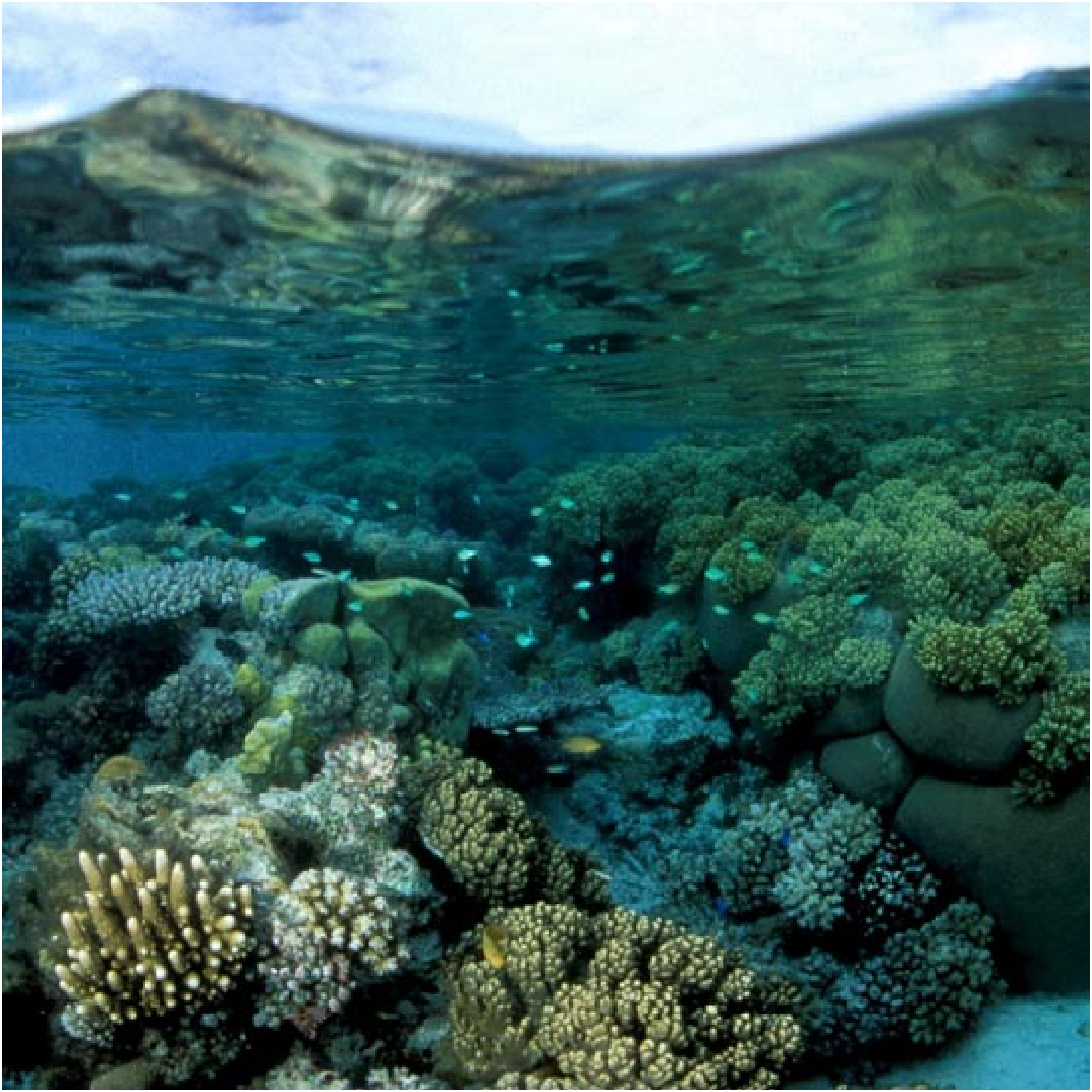


PREFACE

Billions of people rely directly or indirectly on the bounty of the world's oceans and coastal waters.

From fisheries to coral reefs, the marine world generates income, provides livelihoods and is a vital source of protein for coastal communities across the world's Continents. Yet a rising tide of pollution, 80 per cent of which originates from the land, is threatening this wealth by contaminating ecosystems with chemicals, sewage, sediments, pesticides, heavy metals and a range of other impacts. Physical destruction of the coastline is also a growing concern as increasing numbers of people move to the eight per cent of land that is the interface between terra firma and the marine environment.

The principle international response to these issues is the United Nations Environment Programme's (UNEP) Global Programme of Action (GPA) for the Protection of the Marine Environment from Land-Based Sources. The GPA is catalyzing action among governments and, since established in 1995, can point to some important successes not least in the area of cutting oil discharges from the land to the sea alongside assisting in the raising of funds and promoting anti-pollution laws and legislation in countries of both the developed and developing world. But it is clear that governments need to do much more if the promise of healthy and productive and sustainably harvested seas and oceans is to be realized for this and future generations.

This is given even greater urgency by the climate change that is already underway. We need a twin track approach to climate change that eventually involves cutting the emissions of greenhouse gases by up to 80 per cent in order to stabilize the atmosphere. However, we also need adaptation in order to assist countries especially developing nations, to cope with some level of climate change already 'factored into' the system before the big and necessary cuts are realized.

It is clear from this rapid response report that part of the adaptation package must include reductions in the levels of pollution from land-based sources. The team has looked at the recovery of reefs following the massive, climate-linked, bleaching events of the late 1990s and made an important link between rates of recovery and the levels of pollution to which reefs are being exposed. One is left with the inescapable conclusion that the ability of habitats and ecosystems to survive and to recover from extreme temperature events and other likely climatic impacts is going to be related to how well and how sustainably we manage these natural or "nature-based" resources now and over the years to come. These will be important considerations for not only marine based natural resources like coral reefs and mangroves but also terrestrial ones from forests and river systems to wetlands and heathlands.

In doing so we can hopefully help sustain healthy and productive ecosystem services so that they continue to provide food up to purification services – in short a habitable planet – well into what is likely to become a climatically less stable future.

Achim Steiner,
United Nations Under Secretary General
Executive Director United Nations Environment Programme

SUMMARY

Climate change is seriously impacting the world's marine ecosystems.

Massive coral bleaching episodes have impacted the function of the reefs and increased rates of mortality. Coral reefs support over one million plant and animal species and their economic value is projected to more than US $ 30 billion annually. Extreme climatic conditions, however, are most likely to increase in the future with current climate scenarios. Projected increases in carbon dioxide and temperature exceed the conditions under which coral reefs have flourished over the past 500 000 years. Coral reefs are crucial biodiversity hotspots and support both coastal fisheries and tourism in many regions. Coral reefs, however, are in decline in many regions as a result of numerous pressures, including, but not limited to, extreme climate events, unsustainable fishing practices, diseases, sedimentation, and discharge of untreated sewage. Increasing resilience and securing rapid recovery of coral reefs will be essential for the ability of these ecosystems to support coastal fisheries and coastal livelihoods and cultures in the future. However, this resilience and recovery may be seriously impounded by unsustainable coastal infrastructure development and marine pollution from land-based sources. At the current rate of growth, coastal development may impact up to 90% of the tropical and temperate coastlines by 2032 if development continues unchecked. While progress has been made to reduce the discharge and impacts of oil spills and persistent organic pollutants (POP's), there now needs to be a focus on the largest current threats to the coastal marine environment : untreated sewage and piecemeal coastal development.

Over 90% of all the world's coral reefs are found in the Indo-Pacific region of Asia, but also found here are some of the largest increases and levels of emissions of untreated sewage discharge and coastal marine pollution and development. A drastic increase in the appropriate integrated management of coastlines particularly near marine protected areas is urgently needed. Furthermore, an increase in enforcement and extent of protected coastlines, is urgently needed to secure the future diversity and recovery of coral reefs from climate change. Such combined joint protected areas may form source-"islands" or coral "treasure vaults" for re-colonization of damaged areas. Furthermore, the combined cumulative effects of coastal overfishing, marine pollution and coastal development may impact the long-term productivity of the coastal zone. This, in turn, may lower the capacity of these systems to support human livelihoods in the long-term, This challenge requires effective integrated landuse planning including fisheries, tourism and costal infrastructure development, as well as proper watershed management further inland.

CONTENTS

WHY THE MARINE AND COASTAL ENVIRONMENT MATTERS

While the immense importance of marine fisheries is acknowledged worldwide, coastal fisheries provide an essential role for the livelihoods and cultures of a large share of the Worlds population. One third of the worlds population live in the coastal zone, which comprises an area of only 4% of the total land surface (UNEP, 2006). However, the vital role of land-based activity for coastal ecosystems has not been given adequate attention.

Coastal vegetation habitats, such as mangrove forests, can serve as buffers to protect the shore line from wind generated storms while at the same time they absorb silt, nutrients, toxic substances and support fisheries, provide construction materials, medicines and a huge range of other goods used by communities. The clearing of coastal forests increases suspended sediments and nutrients in terrestrial run-off, causing direct and indirect effects on algal and coral growth and competition and coral reef resilience and recovery (McCook 1999, Nyström *et al.* 2000). Even unsustainable watershed management practices far inland may impact coral reefs through increased discharges of silt into the ocean (UNEP, 2004). Areas with extensive natural vegetation and mangroves may have reduced human and property losses following the tsunami event on December 26th, 2004 (UNEP, 2005).

Historical overfishing leading to ecological extinction of entire trophic levels makes ecosystems more vulnerable to other natural and human disturbances such as nutrient loading and eutrophication, hypoxia, disease, storms and climate change (Jackson *et al.* 2001).

In relation to area, the coastlines are also economically of outstanding importance not only for tourism, but also for a large share of coastal fisheries and tropical reefs provides a large range of ecological goods and services (Moberg and Folke 1999). They are also essential to the world's impoverished as they supply a large share of basic free food sources.

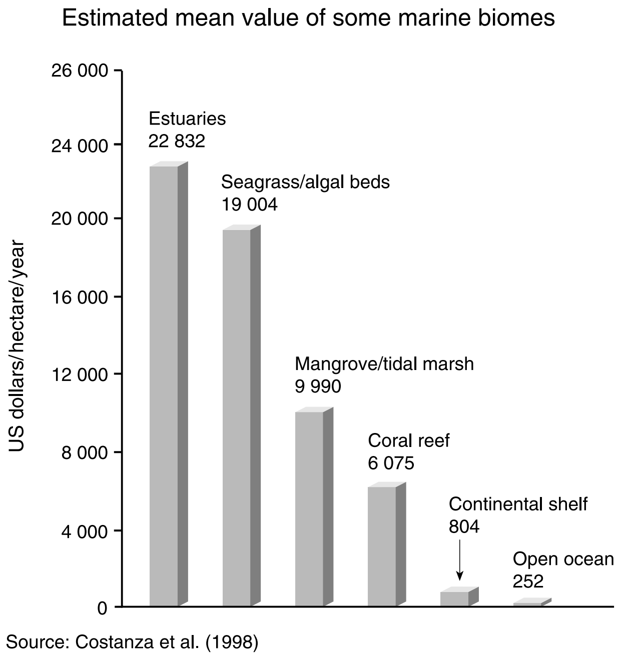
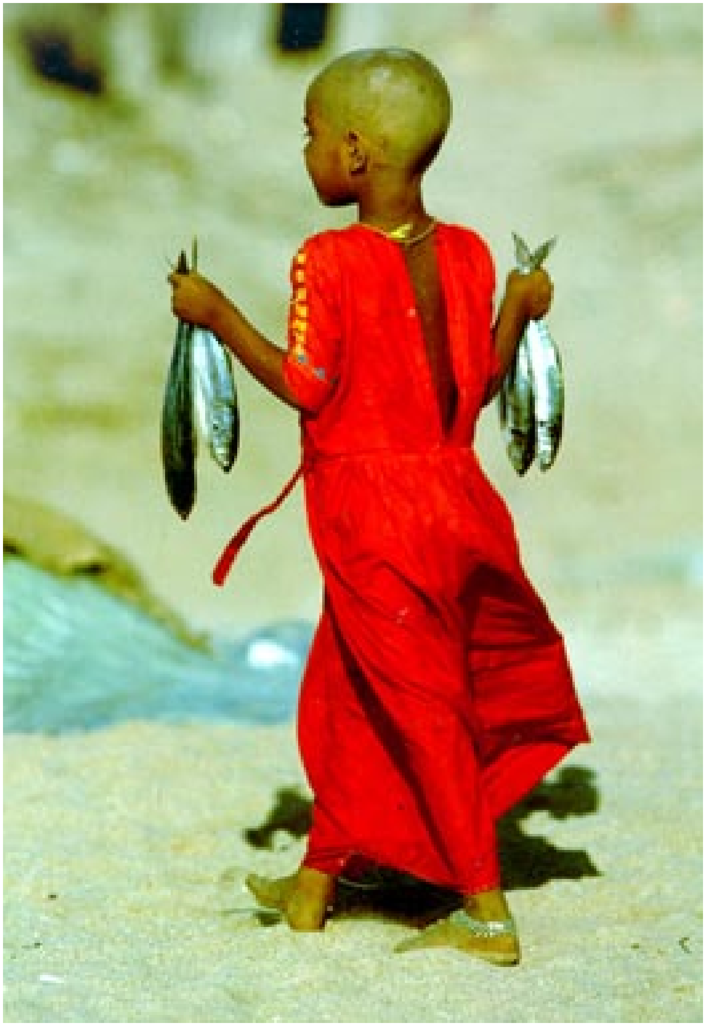
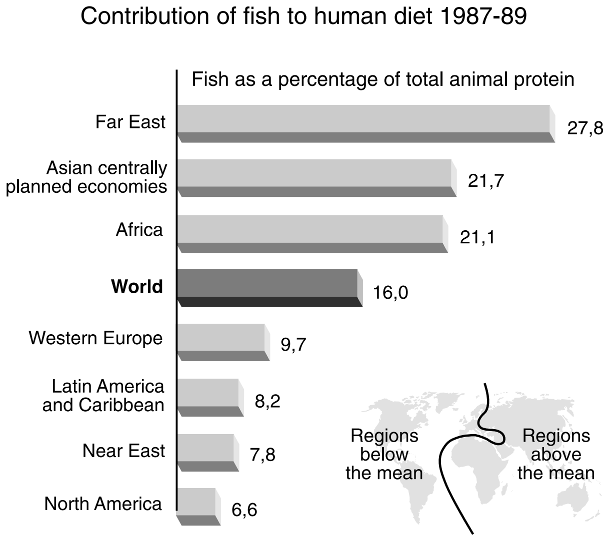


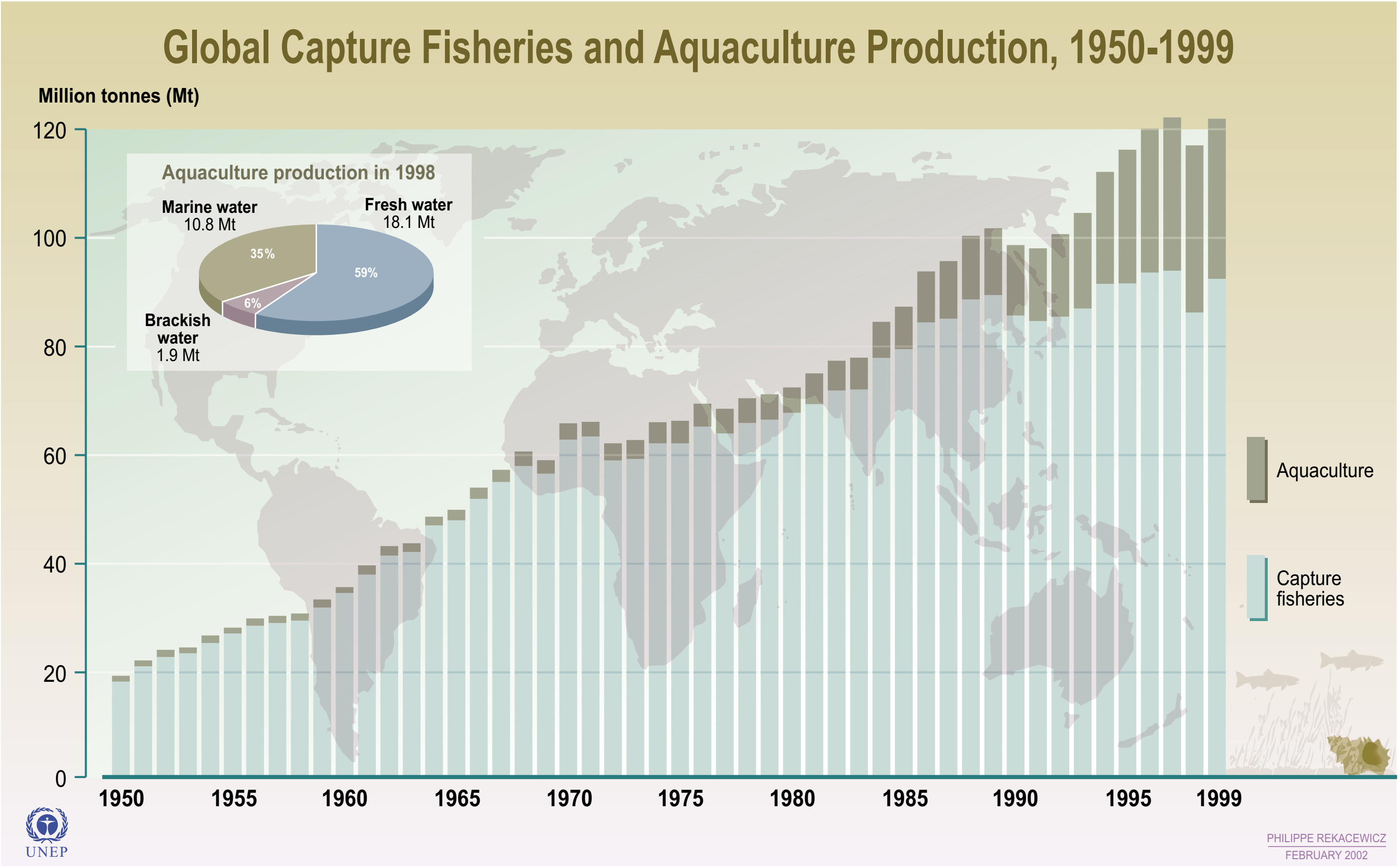
Figure 1. Estimated mean value of some marine biomes. An estimation of the financial value of selected different marine areas. Marine biomes are divided between coral reefs, estuaries, and oceans. The marine biome covers 75% of the earth's surface, and accounts for 90% of the planet's water.





Source: Food and Agriculture Organization of the United Nations (FAO), *Marine fisheries and the law of the sea: a decade of change*, FAO Fisheries Circular n¡853 (FAO, Roma, 1993).

Figure 2. The percentage of fish to the total human diet from various regions in the world. Based on statistics from 1987 to 1989. Fish is the last wild meal in the human diet, but roughly two-thirds of the world's major stocks are now fished at or beyond their capacity, and another 10 percent have been harvested so heavily that populations will take many decades to recover.



Source: *The State of World Fisheries and Aquaculture 2000*, Food and Agriculture Organisation of the United Nations (FAO).

Figure 3. World fisheries and aquaculture production. Shows the amount, in million tonnes, of fish taken by capture and aquaculture fisheries, between the years 1950-1999. Also included is a diagram showing the percentage of the different types of aquaculture in 1998.

WHAT ARE CORAL REEFS?

Coral reefs are marine ridges or mounds, which have formed as a result of the deposition of calcium carbonate by living organisms, predominantly corals, but also a rich diversity of other organisms such as coralline algae and shellfish.

Coral reefs provide a unique habitat characterised by high diversity and density of life. They occur globally in two distinct marine environments; deep, cold water (3-14°C) coral reefs, and shallow, warm water (21-30°C) coral reefs in tropical latitudes.

To date cold-water corals have been identified in 41 countries worldwide, although their full extent is still not fully known (Freiwald *et al.*, 2004). They are found at depths greater than 39m. The following descriptions relate to warmwater coral reefs only. Coral reefs support over a million animal and plant species and their economic value exceeds US $ 30 billion a year.

Warm-water coral reefs are found in circum-tropical shallow tropical waters along the shores of islands and continents. Corals consist of small polyps surrounded by tentacles. They feed through ingesting plankton, and also through the association with symbiotic algae called zooxanthellae. Stony corals deposit calcium carbonate, which over time forms the geological reef structure. Many other invertebrates, vertebrates, and plants live in close association with the scleractinian corals, with tight resource coupling and recycling, allowing coral reefs to have extremely high biodiversity in nutrient poor waters, so much so that they are referred to as 'the Tropical Rainforests of the Oceans'. The table shows that corals have certain zones of tolerance to water temperature, salinity, UV radiation, opacity, and nutrient quantities. The extreme high diversity of coral reefs have led some erroneously to believe that they prefer nutrient rich environments, but, in fact, corals are extremely sensitive to silt and sewage at far lower concentrations than what is classified as hazardous to humans (Nyström *et al.* 2000). Hence, even minor pollution in apparently clear waters can severely impact coral reefs and their ability to support thousands of fish species and other marine life. Sea water quality and human impacts are particularly critical to coral reefs when they are exposed to other stressors or when they are recovering from storms or bleaching events (Burke *et al.*, 2002; Wilkinson, 2002; Brown *et al.*, 2006; UNEP, 2006).

Coral bleaching occurs when the corals are subjected to stress, and their tolerances are exceeded. When this occurs, the symbiotic algae are ejected and the corals lose their colour, and are white. One well documented cause of bleaching is increase of sea surface temperatures (SSTs). If SST rises for a period as little as 1°C higher than the usual average monthly maximum SST during the hottest months of the year, this can result in a bleaching event (Glynn, 1996).

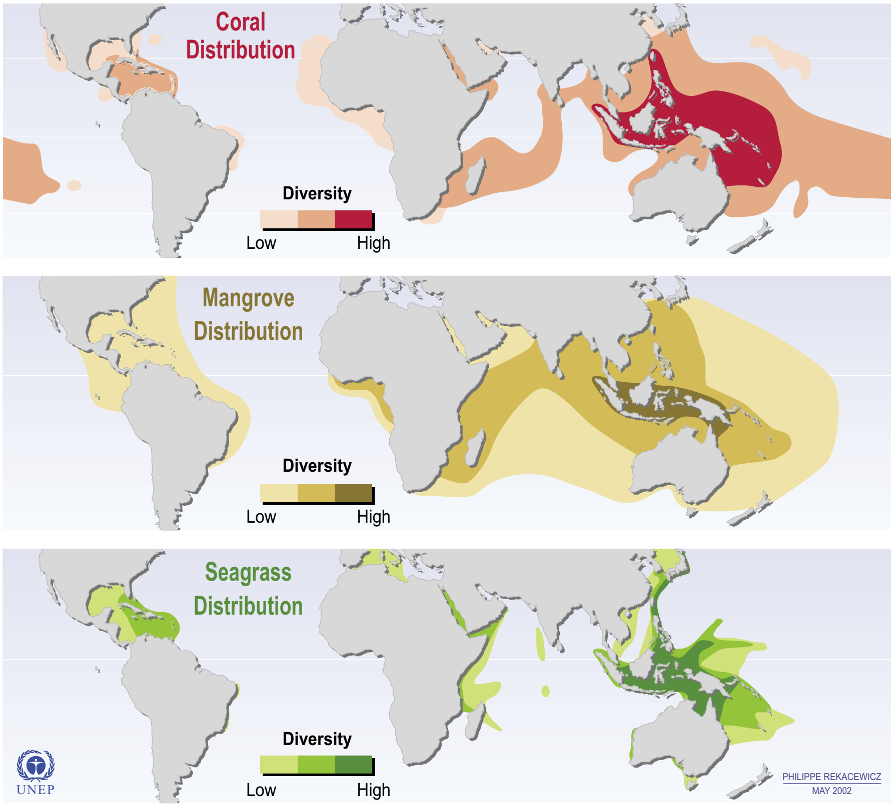
Corals are beautiful living animals that are enjoyed by millions of snorklers and divers world wide, but they are also of vital importance to the whole coral reef ecosystem and for coastal fisheries. If corals die, the characteristic three dimensional structure of reefs that is essential to so many of the services provided, will be lost through natural physical and biological erosion as waves, storms, tsunamis, predators, and other factors affecting corals break it down to rubble.

Top 11 Coral Reef Facts

Number of states/ territories with corals	109
Distribution	30°N - 30°S
Coverage	284 300km2
Number of reef building species described	~800
Temperature range	20-29°C
Salinity range	33-36‰
Depth range	0-100m
Age of living reefs	6 000-9 000 years
Nutrition	Suspended organic matter and photo-synthesis
Ecological impor-tance	~1 million associated animal and plant species
Economic impor-tance	Est >US$ 30 billion/ year

Sources: Spalding *et al*. 2001; Veron, 2000; Cesar *et al*., 2003; Birkeland, 1996; Coté and Reynolds, 2006

Global Distribution of Coral, Mangrove and Seagrass Diversity

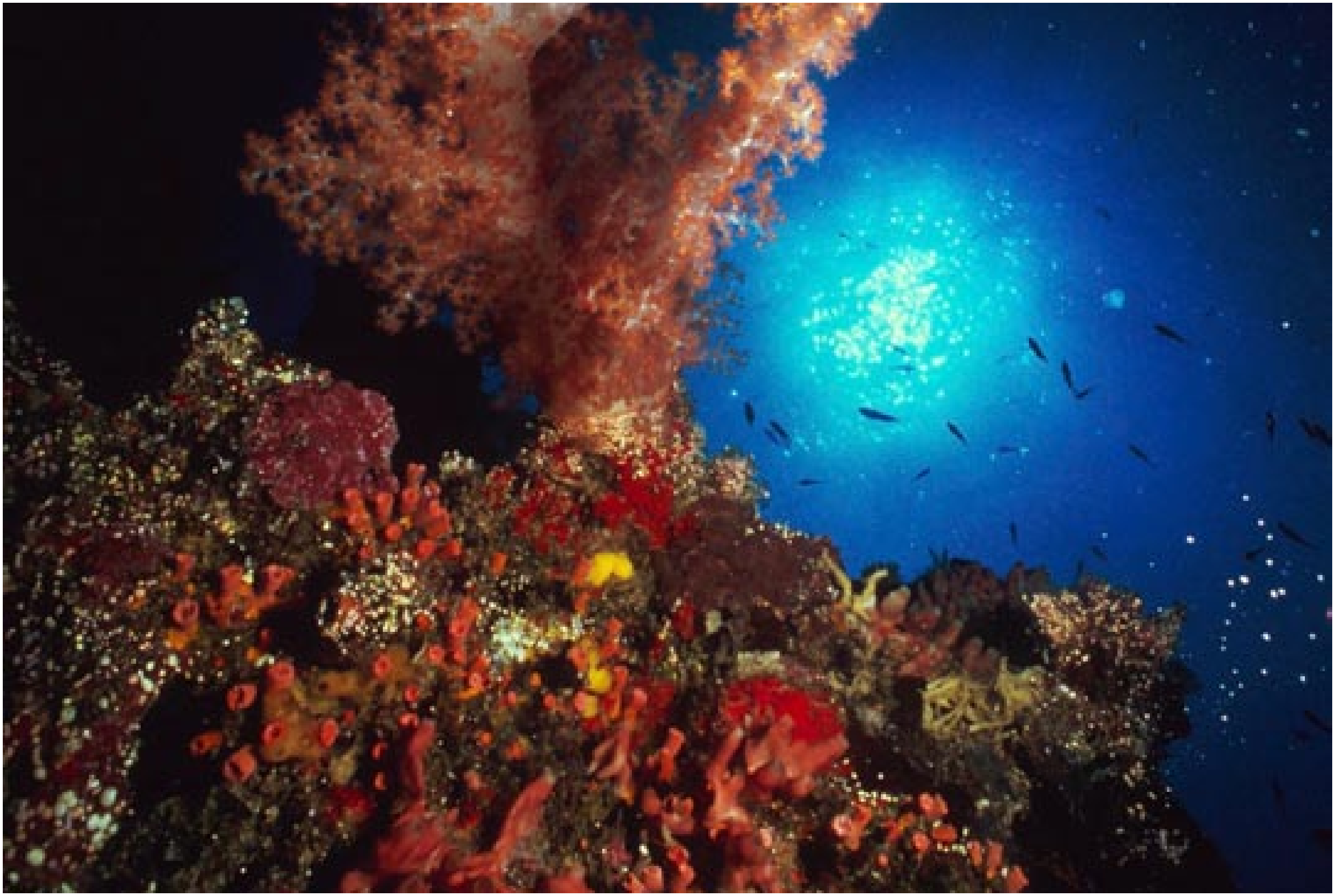


Source: Spalding *et al*., 2001.

Figure 4. Distribution of coral, mangrove and seagrass diversity. Similar to corals, the region of greatest mangrove diversity is in Southeast Asia, particularly around the Indonesian Archipelago (Burke *et al*., 2001). There are three distinct areas of seagrass diversity in the Pacific region: the Indo-Pacific (areas around Indonesia, Malaysia, and Papua New Guinea), the seas around Japan, and southwest Australia (Spalding *et al*., 2002). This graphic illustrates the distribution and biodiversity (low, medium and high diversity) of corals, mangroves and seagrass in the world's coastal and marine areas.

CORAL REEFS AND CLIMATE CHANGE

Projected increases in carbon dioxide and temperature exceed the conditions under which coral reefs have flourished under the past half-million years (Hughes *et al.*, 2003). Currently 30% of reefs are recorded as in decline, and up to 60% may be in decline by 2030 (Wilkinson, 2002). While coral reefs may not disappear entirely, their composition and diversity may decline and change drastically (Hughes *et al.*, 2003). This, in turn, may with other stressors such as marine pollution increase susceptibility to infestations of invasive species, diseases, algae growth or reduce their resilience further and hence their capacity to support fisheries. The causes of the declines appear to be variable, from overfishing and dredging, disease outbreaks and hurricanes, to El Niño-Southern Oscillation induced bleaching episodes and sedimentation and marine pollution (Aronson *et al.*, 2003).



WHAT IS MARINE POLLUTION AND HOW DOES IT AFFECT MARINE LIFE

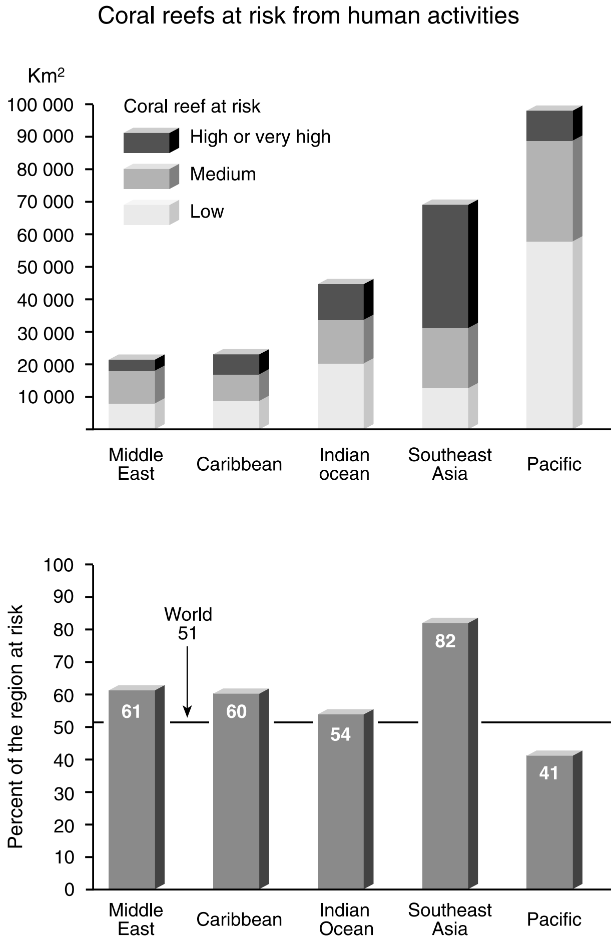
Marine pollution includes a range of threats including from land-based sources, oil spills, untreated sewage, heavy siltation, eutrophication (nutrient enrichment), invasive species, persistent organic pollutants (POP's), heavy metals from mine tailings and other sources, acidification, radioactive substances, marine litter, overfishing and destruction of coastal and marine habitats (McCook 1999, Nyström *et al.* 2000, Bellwood *et al.* 2004). Overall, good progress has been made on reducing Persistent organic pollutants (POP's), with the exception of the Arctic. Oil discharges and spills to the Seas has been reduced by 63% compared to the mid-1980'ies, and tanker accidents have gone down by 75%, from tanker operations by 90% and from industrial discharges by some 90%, partly as a result of the shift to double-hulled tankers (UNEP, 2006; Brown *et al.*, 2006). Some progress on reducing emissions of heavy metals is reported in some re-

gions, while increased emissions are happening in others. Electronic waste and mine tailings are included amongst the sources of heavy metal pollution in Southeast Asia. Sedimentation has decreased in some areas due to reduced river flows as a result of terrestrial overuse for agricultural irrigation, while increasing in other regions as a result of coastal development and deforestation along rivers, water sheds and costal areas, and clearing of mangroves (Burke *et al.*, 2002; McCulloch *et al.*, 2003; Brown *et al.*, 2006; UNEP, 2004, 2006).

A major threat beyond overexploitation of fisheries and physical destruction of marine coastal habitats by dredging, is undoubtedly the strong increase in coastal development and discharge of untreated sewage into the near-shore waters, resulting in enormous amounts of nutrients spreading into the sea and coastal zones (Burke *et al.*, 2002; Wilkinson, 2002; Brown *et al.*, 2006; UNEP, 2006). This, together with changes in salinity, melting sea ice, increased sea temperatures and future changes in sea currents may severely affect marine life and their ability to recover from extreme climatic events.

Around 60% of the wastewater discharged into the Caspian Sea is untreated, in Latin America and the Caribbean the figure is close to 80%, and in large parts of Africa and the Indo-Pacific the proportion is as high as 80-90% (UNEP, 2006). An estimated US$ 56 billion is needed annually to address this enormous wastewater problem. However, the costs to coral reefs, tourism and losses in fisheries and human health risks may be far more expensive. It is also the area where least progress is being made globally.

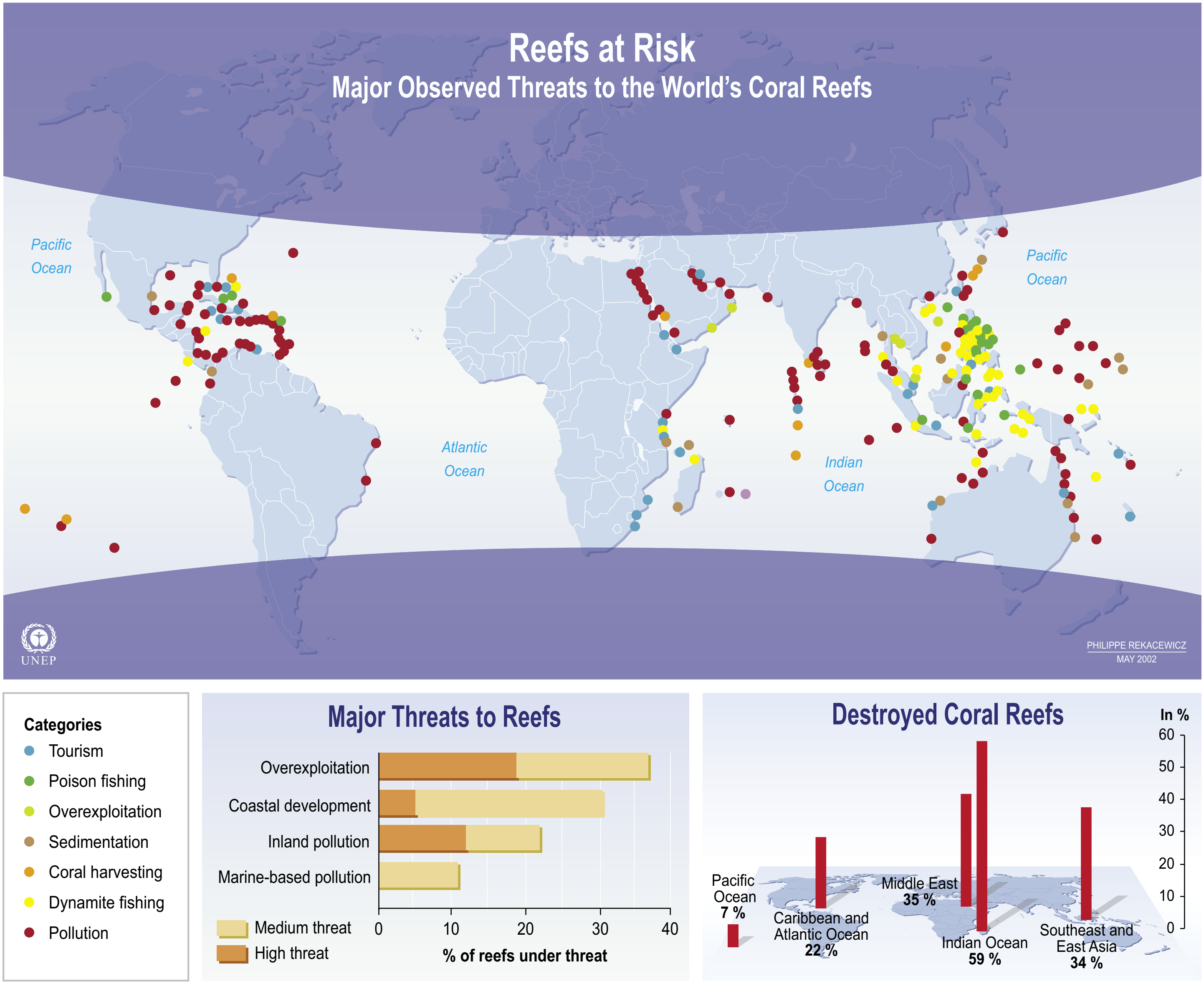
Together with agricultural run-off to the Sea or into major rivers and eventually into the ocean, Nitrogen (mainly nitrate and ammonium) exports to the marine environment are projected to increase at least 14% globally by 2030 (UNEP, 2006). In Southeast Asia more than 600,000 tons of Nitrogen are discharged annually from the major rivers. These numbers may become further exacerbated as coastal populations are depicted to increase from 77 people/km2 to 115 people per km2 in 2025. In Southeast Asia, the numbers are much higher and the situation more severe. Wetlands and mangroves are also declining rapidly, typically by 50-90% in most regions in the past 4 decades (UNEP, 2006). All of the above, together with changes in salinity, melting sea ice, increased sea temperatures and future changes in sea currents may severely affect marine life and its ability to recover from extreme climatic events. Also, it will severely exacerbate the effects of extreme weather and the productivity of coastal ecosystems to supply livelihoods and basic food to impoverished. Hence, the poor management of sewage not only presents a dire threat to health and ecosystems services, it may increase poverty, malnutrition and security for over a billion people (UNEP 2006)



Note: Reefs classified as low risk are not considered in imminent danger.

Source: Lauretta Burke et al. *Reefs at Risk: a map based indicator of threats to the world s coral reefs,* World Resources Institute, Washington DC, 1998.

Figure 5. Coral reefs at risk from human activities. Extreme climatic events, population growth and coastal fisheries account for major causes of coral reef decline – excessive domestic and agricultural waste pouring into ocean waters, poor land-use practices that increase sedimentation of rivers and then of reefs, and over-exploitation of reef resources, often in combination with practices such as harvesting with dynamite and poison, all degrade reefs. These factors, however, also make it far harder for coral reefs to recover from bleaching events.



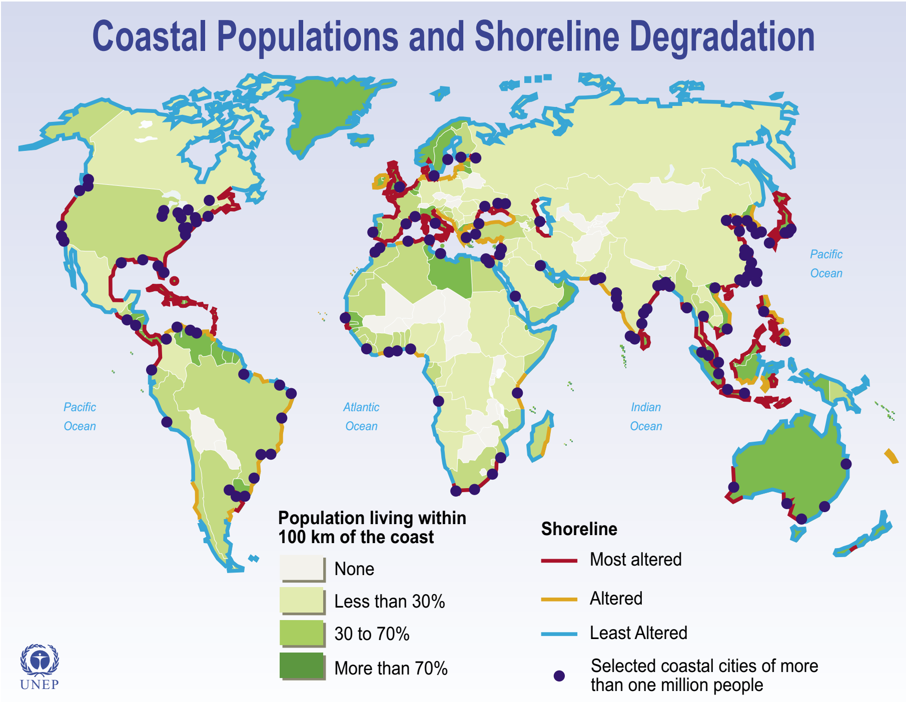
Source: Bryant et al., *Reefs at Risk: a Map-Based Indicator of Threats to the World's Coral Reefs*, World Resources Institute (WRI), Washington DC, 1998.

Figure 6. Threats to the World's coral reefs. Major observed threats to the world's coral reefs include extreme climate events, unsustainable tourism practices, poison fishing for ornamental fish, overexploitation by fisheries, sedimentation, coral harvesting, dynamite fishing and pollution (not in order of priority). This graphic explains which activities or conditions are affecting various coral reefs throughout the world. The graphic 'Major Threats to Reefs' shows the percentage of reefs that are threatened by overexploitation, coastal development, inland pollution and marine pollution, and the degree to which they are under threat. The graphic 'Destroyed Coral Reefs' shows the percentage of coral reefs that have been destroyed in the world's major regions.

Figure 7. These mangroves, in the Trang River Estuary in Thailand, are under threat from upstream discharge of wastewater, industrial facilities and unsustainable aqua culture practices – particularly commercial shrimp farming. From 1975 to 1993, it is estimated that about half of Thailand's mangroves along its 2,560 kilometer coastline have been lost. The larger area of the Had Chao Mai Marine National Park, the Ta Libong Island Non-Hunting Area and the Trang River Estuaries has been designated a Ramsar Wetland Site and supports over 200 bird species including many "Critically Endangered", "Endangered", "Vulnerable" and "Threatened" species according to the IUCN Red List (IUCN, 2006).

In these two Landsat images shrimp farms appear as bluish purple squares located near the streams. Between the earlier image acquired in January, 1990 and the later image acquired approximately 11 years later there is an explosion in shrimp farming throughout the estuary.


Thailand
Khao Kantang
Khuen Ko Khwai



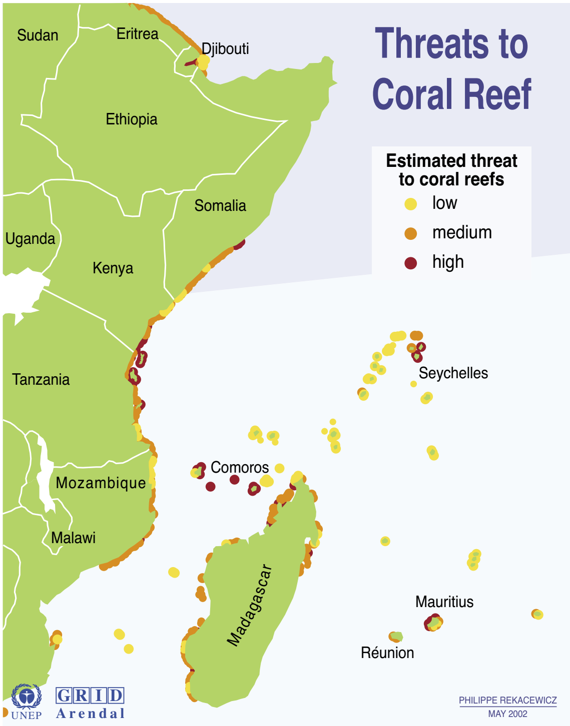
Source: Burke et al., World Resources Institute, Washington DC, 2001; Paul Harrison and Fred Pearce, *AAAS Atlas of Population and Environment 2001*, American Association for the Advancement of Science, University of California Press, Berkeley.

Figure 8. Coastal population and shoreline degradation. This graphic shows that the coastal areas with the greatest population densities are also those with the most shoreline degradation or alteration. The graphic shows the proportion of the population that lives within 100 km of the coast, for each of the world's nations. It also shows the locations of selected coastal cities with a population of more than one million people.

Figure 9. With a population over 1.4 million (and approximately twice that number in the greater metropolitan area), Kuala Lumpur is the largest city in Malaysia and is growing rapidly. Its sprawl is now encroaching on the mangrove forests at the coastline (approximately 35 kilometers to the west of the city centre).

These Landsat satellite images from 1974 and 2005 show the gradual spread of development and the loss of mangrove forest that has resulted. By 1975, many areas of mangrove had already been converted to agriculture. As thirty years pass, the agricultural areas expanded and more mangroves were converted to farms. At the same time, these images show the agricultural areas being converted to industrial and urban land use. Elsewhere along the Malaysian coastline, mangroves are rapidly being converted to commercial shrimp farms. Forestry Department statistics show that peninsular Malaysia had 85,800 hectares (214,500 acres) of mangrove swamp forests in 2003, down from 86,497 hectares just one year earlier.

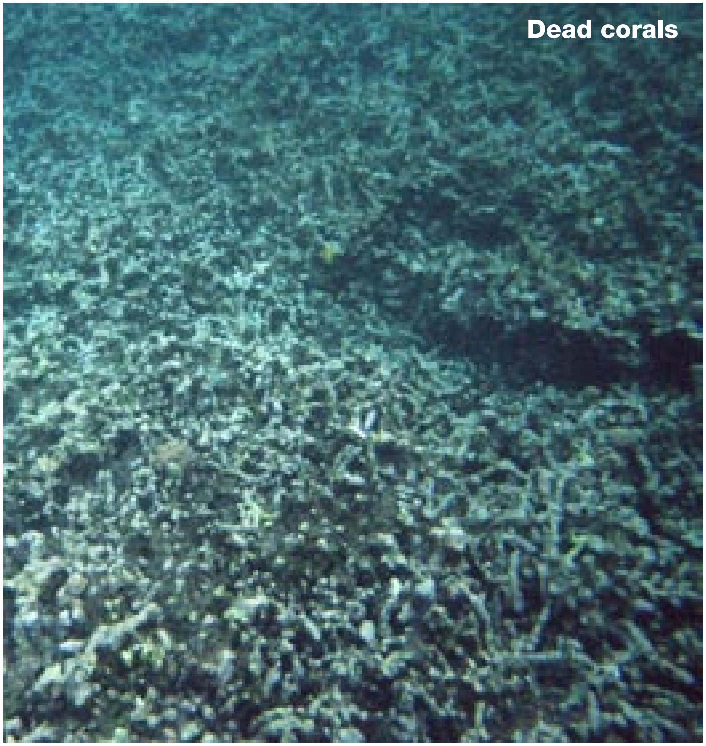

Malaysia
Kuala Lumpur



Source: WRI, ICLARM and UNEP, 1998.

Figure 10. Threats to coral reefs in Eastern Africa. Human land use along coasts and in major river basins can threaten coral reefs through toxic material inputs to coastal ecosystems. This graphic shows the areas of low, medium and high estimated threats to coral reefs on Africa's eastern coast.

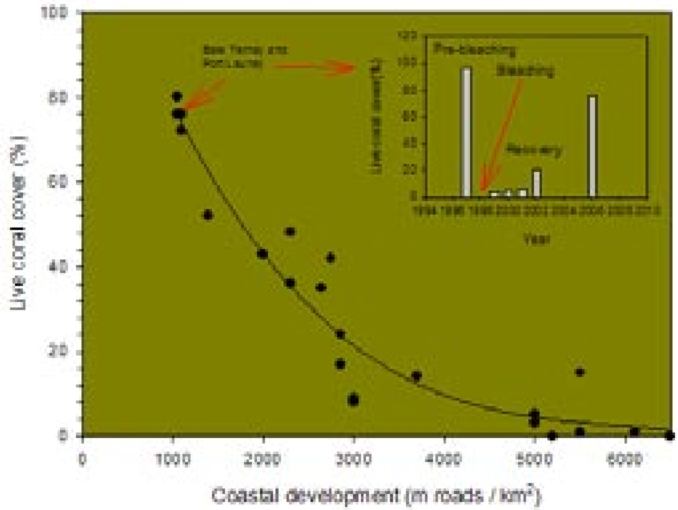
RESILIENCE AND RECOVERY OF CORAL REEFS AND COASTAL HABITATS



By far the most coral reefs are located between latitudes 30° N and S, and of these nearly 92% are located in the Indo-Pacific (Spalding *et al.*, 2001). This region was also severely hit by the El Niño event of 1998. The Seychelles and Comoros were hit hard (Wilkinson, 2002). Another more localized bleaching event occurred in 2002 in those areas. There is extensive documentation that changes in the salinity of water, and in particular run-off of silt, nutrients, sewage and other forms of coastal pollution associated with agricultural production, logging, land reclamation, clearing of vegetation for industrial and coastal development may isolate, kill, or deplete coral reefs (McCook 1999, Nyström *et al*. 2000, Bellwood *et al* 2004). However, these factors also serve as an essential role in hindering recovery of coral reefs following storms or severe temperature events resulting in bleaching of coral reefs.

Coastal development in terms of settlements, resort or industrial development reduces the diversity of the coastal vegetation and destroys significant areas, such as mangroves. These ecosystems play an essential role in limiting silt and nutrient outflows to the nearshore marine environment, including run-off of sewage animal waste and top soil during the heavy tropical rains or from rivers.

A survey by a UNEP team in collaboration with Nature Seychelles monitored the re-colonization of coral reefs following the bleaching event in 1998, and the later smaller ones in 2001-2003. The results revealed a remarkable relationship between coastal infrastructure development (roads, settlements and buildings) and loss of coastal vegetation diversity, and also great differences in the recovery rate of bleached corals (see box on page 28).



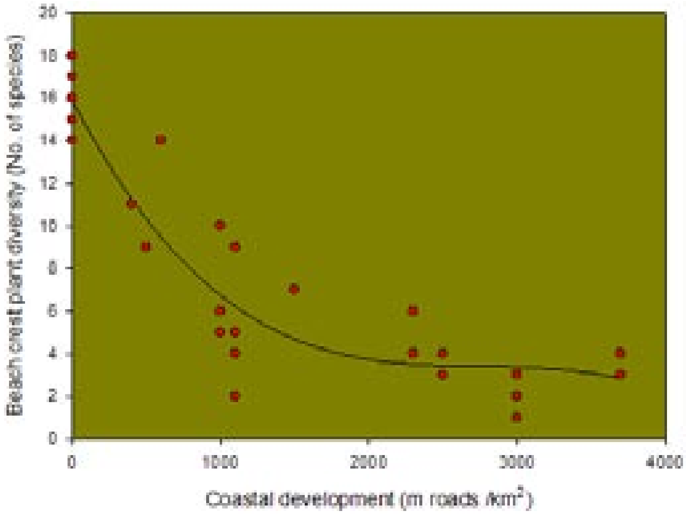


Figure 11. Recolonization of corals following bleaching along the coasts of Mahé island, Seychelles. With increasing development, silt, land reclamation and sewage cover corals with sand and algae, slowing down recolonization substantially. The Baie Ternay and Port Launay sites were hit badly by the bleaching events, but have been rapidly recolonized by soft and leather corals, as well as *Porites* sp. Correspondingly, the sites near heavy development have shown little or no recovery in the same period, suggesting that their ability to recover is much less (Source: Wilkinson, 2002, Global unit SO survey data with Nature Seychelles).

Figure 12. The impacts of coastal development and clearing of coastal vegetation in the beach crest on costal vegetation diversity within 5-25 m of the beach. Development often results in the clearing of coastal vegetation, which then again may increase run-off into rivers, creeks and into the ocean directly during heavy rains or as a direct result of coastal erosion. Most important, however, is likely marine pollution originating from land based sources. (Data from Mahé, Praslin and La Digue, Seychelles 2002-2006).

The Status of the coral reefs in the Indian Ocean and in particular the Seychelles prior to and following the major bleaching event of 1998, where sea surface temperature in some areas exceeded 34° C, has been published in several reports. The Seychelles have had a high level of environmental awareness with many protected areas and good policies and legislation, although on the east side of the main island, Mahé, a substantial share of the coastal and marine ecosystems (seagrass and marine algal beds, reefs, etc.) have been covered by land reclamation and damaged by coastal development and pollution. Coral reefs in the entire region including Madagascar, La Reunion, Comoros, Mauritius and the Seychelles were severely damaged during the bleaching event, resulting in losses of 50-95% of live coral cover including losses in several marine protected areas. Large proportions of the hard corals, such as *Acropora* species, died. For example in the St. Anne Marine National Park and Bay Ternay more than 95% of the corals were dead by 1999. However, in surveys in the following years, cover by soft corals and stony coral species like *Porites* sp. increased rapidly in Bay Ternay, the MPA the least affected by coastal development on the main island of Mahé. In the following years coral cover nearly doubled annually, reaching 20% in 2002, though not of the slow-growing branchy corals like *Acropora* and *Pocillopora* sp.

A task force team with the assistance of Nature Seychelles monitored coastal vegetation in 2004 and coral coverage from 120 dives on 22 sites in 2006. Dives were confined to coral reefs with visible structure remaining, minimum five plots of 3x3 meter per site at 2-6 m depths. Coral cover, live coral cover, no. of day-active fish species, rubble cover, bottom topographic ruggedness, coastal distance and various measures of coastal development incl. settlements, infrastructure and vegetation diversity were recorded. The monitoring revealed that around the entire island, recovery varied substantially (from 5-70% recovery of the fastest growing corals) not just with impacts of wave erosion, but particularly with coastal development and pollution. Many dead reefs were overgrown with algae caused by higher nutrient contents near developed areas, and surface run-off of silt, which apparently reduced re-colonization rate substantially. *Acropora* corals seemed to have survived mainly in sites with either cooler water, more current and in sites less exposed to development and pollution on the East coast. The results confirm findings and claims worldwide that land-based pollution, reclamation, clearing of coastal vegetation and poor sewage control can damage reefs (Burke *et al*., 2002). More importantly, they demonstrate that protection of coastal land areas around marine protected areas is essential for reducing local pollution and facilitating recolonization of corals. On Mahé island, and other populated granitic islands, curbing coastal development and capping land reclamation may become essential for improving resilience of marine ecosystems by, for example, securing the recolonization and healthy growth of damaged reefs.

Figure 13. The Huang He (Yellow River) is the muddiest river on Earth and is China's second longest river, running 5 475 km (3 395 miles) from eastern Tibet to the Bohai Sea. The Huang He's yellow color is caused by its tremendous load of sediment, composed primarily of mica, quartz, and feldspar particles. The sediment enters the water as the river carves its way through the highly erodable loess plateau in north-central China (Loessial soil is called huang tu, or "yellow earth," in Chinese). Centuries of sediment deposition and dike building along the river's course has caused it to flow above the surrounding farmland in some places, making flooding a critically dangerous problem. Where the Huang He flows into the ocean, sediments are continuously deposited in the river delta, where they gradually build up over time. Between 1979 and 2000 - as these satellite images show - the delta of the Huang He river expanded dramatically. Several hundred square kilometres of newly formed land were added to China's coast during this period.


C H I N A
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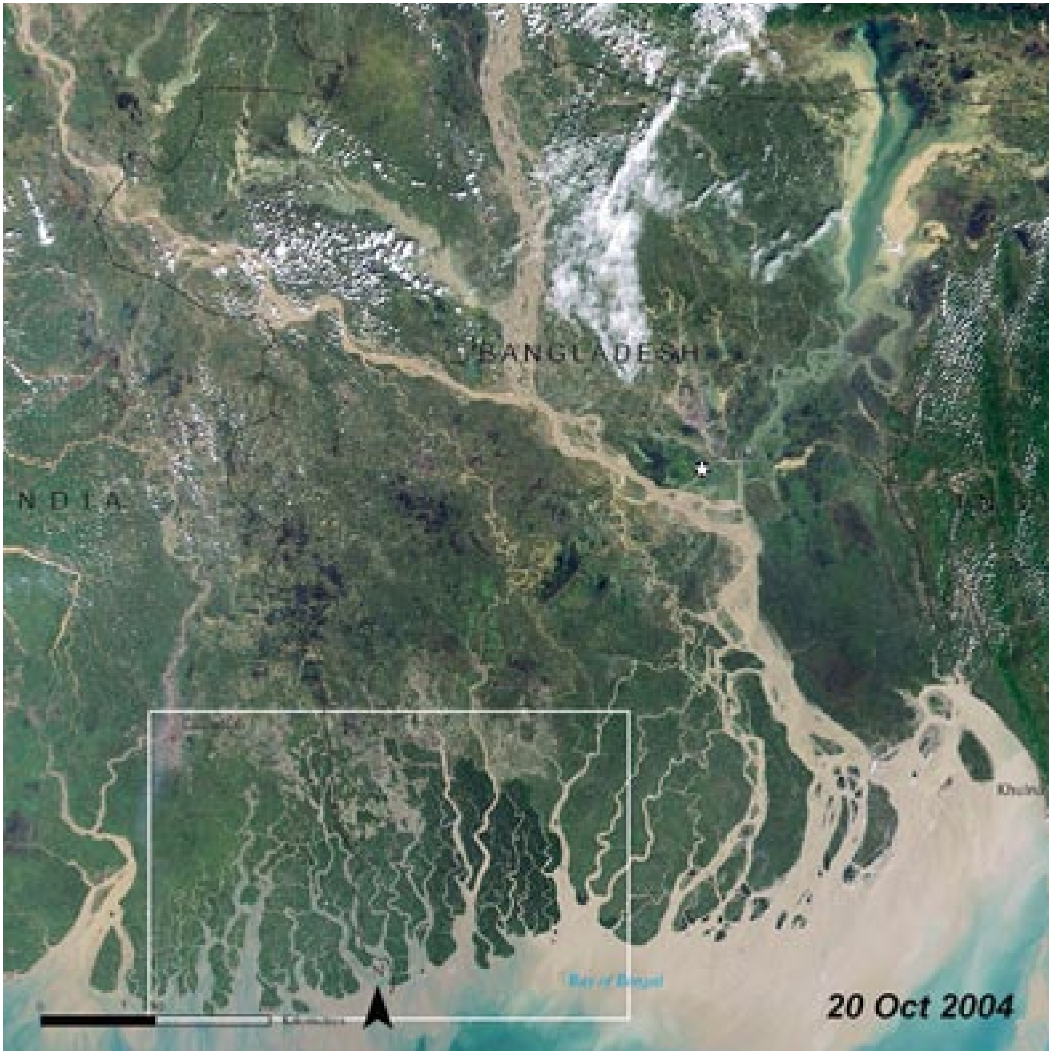

Figure 14. Sundarban, the largest mangrove forest of the world, is situated in the southwestern part of Bangladesh and in the West Bengal state of India. Guarded by the Bay of Bengal, Sunderban is an excellent example of the coexistence of human and terrestrial plant and animal life. Despite high population pressure and environmental hazards such as siltation, cyclone flooding and sea level rise, the areal extent of the mangrove forest has not changed significantly in the last 25 years. In fact, with improved management, the tiger population has increased from a mere 350 in 1993 to 500-700 in 2000. Ecotourism is increasing as well. However, while sufficient data is not available, several reports suggest that forest degradation has been occurring in many parts of Sundarban. The Sundarban mangrove forests are also becoming more vulnerable due to the significant rise of shrimp farming in the region. The increase of shrimp farming has negatively affected agriculture and also contributed to the loss of mangrove forests during the past two decades.


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BANGLADESH
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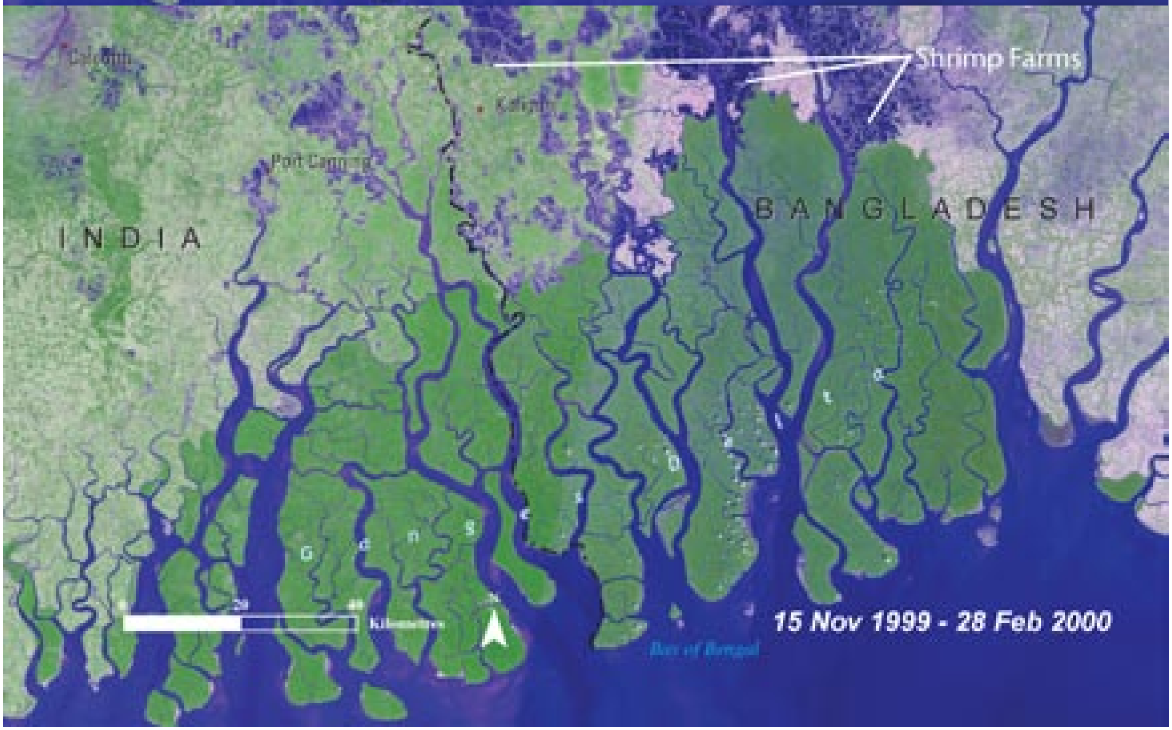
Shrimp Farms
Port Canning
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GLOBAL OUTLOOK

Even with the full range of current climate predictions, increased warming events and storms are expected to increase in frequency in the future along with coastal population growth and development (Sheppard 2003). In this regard, control of marine pollution and integrated management of coastal development will play an essential role in building resilience and enhancing the ability and capacity of coral reefs to recover from severe events (Bellwood *et al.* 2004). While reducing pollution may not prevent corals from bleaching, it will help to ensure that the environment remains suitable for recolonization and rebuilding of reefs that have suffered mortality. Furthermore, it may enable reefs to become rapidly recolonized by soft and leather corals, thus reducing their likelihood of destruction by waves and storms. Such sites may become highly valuable for supplying new coral larvae recruitment to sites destroyed by bleaching. Nearly 80% of the marine pollution comes from coastal land based sources (UNEP, 2006). Hence, it is critical that (a) an ecologically representative system of effectively managed MPAs is implemented, and (b) that marine protected areas incorporate the coastal zone; and (c) that development and management of activities in the coastal zone elsewhere are undertaken in a responsible manner and in accordance with the principles of integrated coastal zone management. Current projections (Wood, L. MPA NEWS Vol. 7, No. 5, November 2005) indicate that international commitments for protection of the marine and coastal zones will not be realised. Using the current rate of designation:

- The World Parks Congress target of creating a global system of MPA networks by 2012 – including "strictly protected areas" amounting to at least 20-30% of each habitat will not be reached until at least 2085 (or probably much later
- The recommendation by a subsidiary body of the UN Convention on Biological Diversity (CBD), that 10% of all marine and coastal ecological regions be conserved in MPAs by 2012, will not be met until 2069.

MPAs further need to be of a significant size, effectively managed, and designed and implemented in such a way to facilitate the conservation of marine biodiversity and the associated ecosystem services, including close regulation of the adjacent land-based activities to reduce pollution.

In 2002, more than 70% of the tropical and temperate coasts were heavily impacted by development of resorts, hotels, settlements and other human infrastructure. By 2032, this figure may have risen to as much as 90% (range 81-95%) (Data from GLOBIO, prepared for this report, www.globio.info), with substantial increases in discharges of nutrients and silt into the marine environment. This will lead to massive reductions in the productivity of the marine environment, so essential to the livelihoods, cultures and food security of several hundred million peoples in Asia.

As development is currently the most severe in areas of high biodiversity, including extensive land reclamation on former reefs, development of coastal land and marine protected areas in combination may prove essential for securing the future survival and recovery of coral reefs in the coming decades. Formation of marine protected areas without the protection/ management of primary land and coastal threats will, in association with growing coastal development, result in severe losses in reserves and reduced capacity of marine ecosystems to support also coastal people. Furthermore, protection and improved coastal land zone management is essential for key ecosystems like coral reefs to recover from bleaching events. These MPA's also need to be enforced and be of a significant size in order to have an effect. Given the extremity of some of the bleaching events, with up to 95% mortality, it is essential that immediate concern is given to coastal protection of land-based pollution sources in order for "islands" of coral reefs to survive (Wilkinson 1996, Hughes *et al.* 2003, Pandolfi *et al.* 2003). These areas may play a vital role in the future as sources of both fish and coral larvae needed for recolonization of depleted or severely damaged reefs elsewhere.

Using the World Database on Protected Areas, together with recent updates, approximately 23% of all coral reefs fall within some classification of legal protection, while 11% are within classes of stricter management regimes (IUCN management categories I-IV)(Spalding *et al.*, 2006). Many MPA's, however, are small and enforcement is highly variable. The percentage of combined land and marine protection, however, is much less. If a substantial increase in combined coastal land and marine protected areas will not take place within the next two decades, extensive areas of coral

reefs may not recover from future bleaching events as a result of overgrowth of algae, eutrophication and destruction from waves and storms.

Furthermore, the combined cumulative effects of coastal overfishing, marine pollution and coastal development may impact the long-term productivity of the coastal zone. This, in turn, may lower the capacity of these systems to support human livelihoods in the coastal zone. This challenge requires effective integrated landuse planning including fisheries, tourism and costal infrastructure development, such as promoted by ICARBM (Integrated Coastal Area and River Basin Management). More than ever, the future sustainability of these regions will require an implementation of effective combined programmes in the short-term.

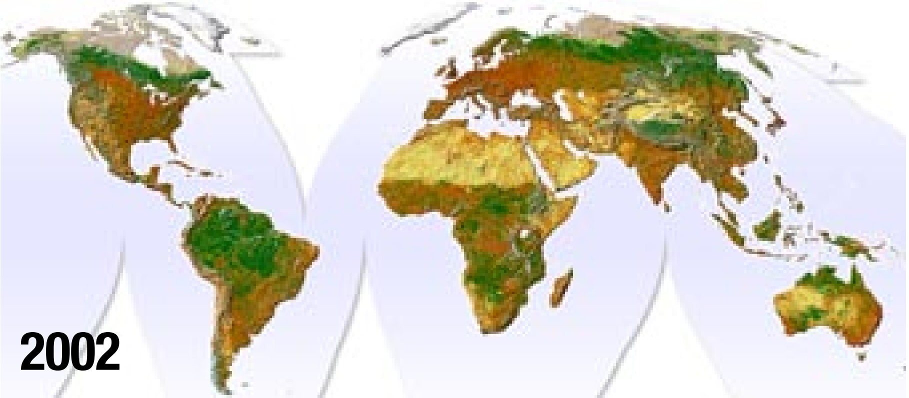
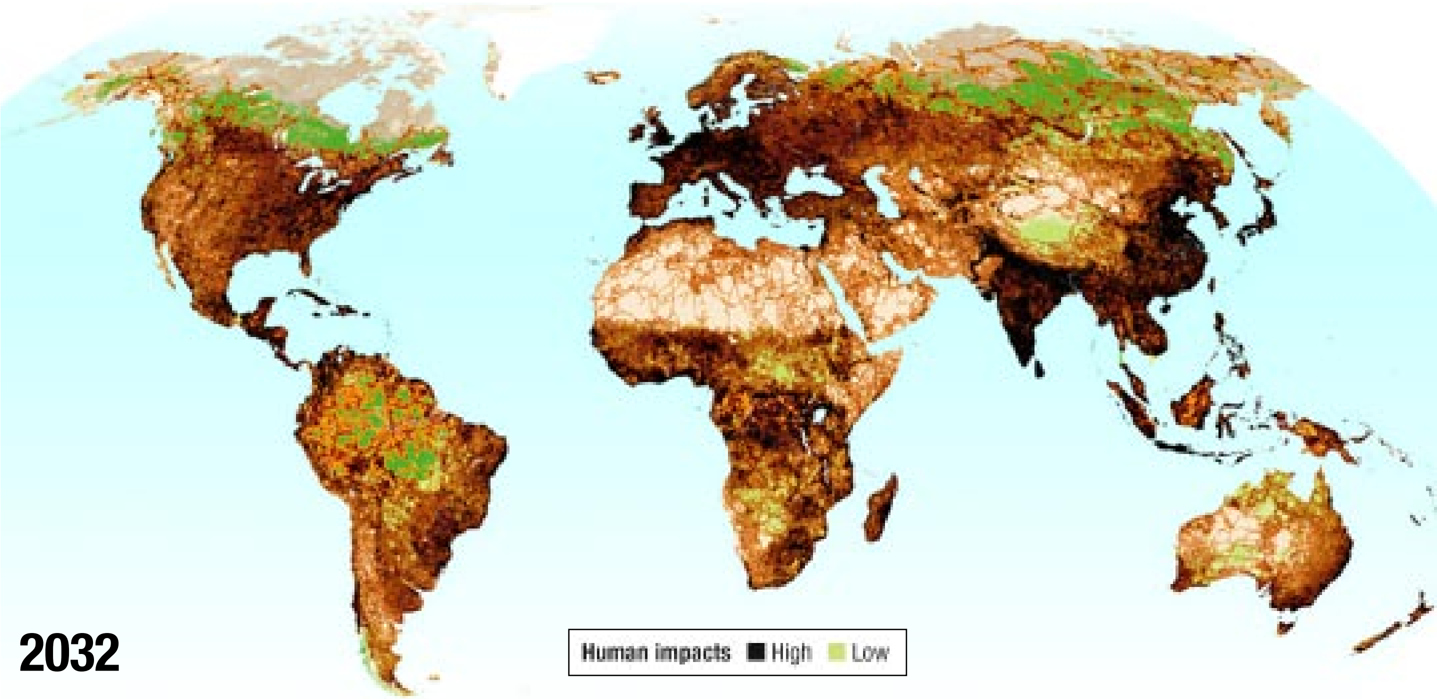


Figure 15. Projections of continued infrastructure and coastal development project an increase in impacted coastlines from the current average of 70% between 30° N and S, to 81-95% by 2032 (dependent upon scenario). In Southeast Asia and the Indo-pacific region the degradation rate is much higher, at the same time as this regions contains near 92% of the World's coral reefs. Development of marine protected areas must be associated with an increase in protected areas along the coasts to secure the future resilience of these reefs to climate change, and to protect the coastal livelihoods and cultures.



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REFERENCES

Aronson, R. B., Bruno, J. F., Precht, W. F. *et al.*, 2003. Causes of Coral reef degradation. Science 302: 1502.

Bellwood, D.R., Hughes, T.R., Folke, C. and Nyström, M. (2004). Confronting the coral reef crisis. Nature 429: 827-833

Birkeland, C. (Ed.). 1996. Life and death of coral reefs. Chapman and Hall, 536 p.

Brown, C., Corcoran, E., Herkenrath, P. and Thonell, J. 2006. Marine and coastal ecosystem,s and human wellbeing. Synthesis. UNEP-WCMC, Cambridge, 65 p.

Burke, L., Selig, E. and Spalding, M. 2002. Reefs at risk in Southeast Asia. World Resoruces Institute, www.wri.org, Wasgington D.C.72 p.

Cesar, H., Burke, L., Pet-Soede, L. 2003. The economics of worldwide coral reef degradation. Cesar environmental consulting, 23 p.

Coté, I. M. and Reynolds, J. D. (Eds). 2006. Coral reef conservation. Conservation Biology 13. 588 p.

Freiwald, A., Fosså, J. H., Grehan, A., Koslow, T. and Roberts, J. M. 2004. Coldwater coral reefs. UNEP-WCMC, Cambridge, www.unep-wcmc.org, 84 p.

Glynn, P.W. 1996. Coral reef bleaching: Facts, hypotheses and implications. Global Change Biology 2: 495-509

Hughes, T.P., Baird, A.H., Bellwood, D.R., Card, M., Connolly, S.R., Folke, C., Grosberg, R., Hoegh-Guldberg, O., Jackson, J.B.C., Kleypas, J., Lough, J.M., Marshall, P., Nystrom, M., Palumbi, S.R., Pandolfi, J.M., Rosen, B. and Roughgarden, J. (2003). Climate change, human impacts, and the resilience of coral reefs. Science 301: 929-933

IUCN 2006. 2006 IUCN Red List of Threatened Species. http://www.iucnredlist.org.

Jackson, J.B.C., Kirby, M.X., Berger, W.H., Bjorndal, K.A., Botsford, L.W., Bourque, B.J., Bradbury, R.H., Cooke, R., Erlandson, J., Estes, J.A., Hughes, T.P., Kidwell, S., Lange, C.B., Lenihan, H.S., Pandolfi, J.M., Peterson, C.H., Steneck, R.S., Tegner, M.J., Warner, R.R. (2001). Historical overfishing and the recent collapse of coastal ecosystems. Science 293: 629-638

McCook, L.J. 1999 Macroalgae, nutrients and phase shifts on coral reefs: scientific issues and management consequences for the Great Barrier Reef. Coral Reefs 18: 357-367

McCullough, M., Fallon, S., Wyndham, T., *et al*. 2006. Coral record of increased sediment flux to the inner Great Barrier Reef since European settlement. Nature 421: 727-730.

Moberg, F. and Folke, C. 1999. Ecological goods and services of coral reef ecosystems. Ecological Economics 29: 215-233

Nyström, M., Folke, C. and Moberg, F. 2000. Coral reef disturbance and resilience in a human-dominated environment. Trends in Ecology and Evolution 15: 413-417

Pandolfi, J.M., Bradbury, R.H., Sala, E., Hughes, T.P., Bjorndal, K.A., Cooke, R.G., McArdle, D., McClenachan, L., Newman, M.J.H., Paredes, G., Warner, R.R., Jackson, J.B.C. (2003). Global trajectories of the long-term decline of coral reef ecosystems. Science 301: 955-958

Sheppard, C.R.C. 2003. Predicted recurrence of mass coral mortality in the Indian Ocean. Nature 425: 294-297

Spalding, M., Ravilious, C.,and Green, E. P. 2001. World atlas of coral reefs. UNEP-WCMC, Cambridge, 424 p.

Spalding *et al*. 2006. Nature, in press.

UNEP. 2004. Fall of the Water. Nellemann, C. (Ed.). United Nations Environment Programme, www.unep.no.

UNEP. 2005. After the Tsunami – rapid environmental assessment. United Nations Environment Programme, www.unep.org

UNEP. 2006. The state of the marine environment-trends and processes. United Nations Environment Programme and the Global Programme of Action for the Protection of the Marine Environment from Land-based Activities (GPA) of the United Nations Environment Programme (UNEP), The Hague. 52 p.

Veron, J. E. N. 2000. Corals of the World. (Ed. M. Stafford-Smith). Australian institute of marine science and CRR R Qld Pty Ltd, 463 p.

Wilkinson, C.R. 1996. Global change and coral reefs: Impacts on reefs, economies and human culture. Global Change Biology 2: 547-558

Wilkinson, C. 2002. Status of coral reefs of the world: 2002. United States coral reef taskforce, Australian Institute of marine Science, Townsville, Australia. 378 p.

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