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The State of the Reefs – ICRI's Major Concern

A. Introduction

Coral reef ecosystems benefit humans commercially, recreationally, aesthetically and environmentally and are among of the most diverse, complex, and beautiful ecosystems on earth. Because of the interconnections which can develop between coral reef, mangrove forests and seagrass beds, these two ecosystems are also considered in this report, where these are found to lie in close proximity to coral reefs.

The declining state of coral reef ecosystems has sparked concern by scientists, managers and government officials. The 1991 National Science Foundation, Environmental Protection Agency and National Oceanic and Atmospheric Administration sponsored workshop on coral bleaching, coral reef ecosystems and global climate change, the Seventh International Coral Reef Symposium in 1992 at Guam and the meeting of experts on "Global Aspects of Coral Reefs: Health, Hazards and History" held at the Rosentiel School of Marine and Atmospheric Science in Miami all stressed these concerns. In addition, the 1992 UN Conference on Environment and Development specifically mentioned coral reefs, seagrass beds, and mangroves as marine ecosystems of high biodiversity and production and recommended that they be accorded high priority for identification and protection. The growing support for the International Coral Reef Initiative (ICRI) by nations around the world confirms the seriousness of the problem.

The abundant biological diversity of the coral reef ecosystem, not only includes coral and the commercially important species associated with the reef but also tens of thousands of other plant and animal species. Thus, the status and trends of this ecosystem are not easily evaluated. Historically, most coral reef surveys have been limited to discrete reefs or species or have been time limited (Rogers 1985; Dustin and Halas 1987; Porter and Meier 1992; Bythell et al. 1992; Ginsburg 1994). The status and trends of complete coral reef ecosystems around entire islands or

reef tracts (i.e., the entire Florida reef tract) have never been comprehensively evaluated because of the complexity, length of time, and cost of such endeavors. Because of this lack of a comprehensive understanding of the status and trends of coral reef ecosystems on large scales, this report takes a very broad look at: general patterns in the status and trends of these ecosystems today, and what would be the consequences of coral reef ecosystem degradation to human populations. The references cited are mainly those of comprehensive works and were chosen to help lead the reader to further sources of information.

Points on the maps in the global perspective include published and unpublished reports but not unwritten reports. They represent literature citations that have been entered into the Reef Base system to date and represent about 20 percent of what is actually available. They are roughly representative of the stresses on a broad scale.

The regional reef maps are the best available, produced from an ongoing global coral reef mapping project. The lines on the map are restricted to shallow and emergent reefs (which make up perhaps 10 percent of the total area of reefs in the world), but they provide a fair portrayal of the general distribution of reefs. Likewise the mangrove data are prepared from an ongoing global mapping initiative, although data are currently incomplete or missing from some countries.

B. Global Perspective

1. Status and trends

Coral reef ecosystems are under increasing pressure, and the threats are primarily from human interactions. In some cases, natural disturbances further compound the effects of anthropogenic stress. Of the approximate 600,000 km² of coral reefs world-wide, it is estimated that about 10 percent have already been degraded beyond recovery and another 30 percent are likely to decline significantly within the next 20 years. In addition, unless effective integrated coastal zone management is implemented more than two-thirds of the world's coral reefs may become seriously depleted of corals and associated biota within two generations. Coral reef ecosystems at greatest risk are in South and Southeast Asia, East Africa, and the Caribbean, however, people have damaged or destroyed reefs in over 93 countries (IUCN, 1993).

Rapid population growth and migration to coastal areas where coral reef ecosystems occur exacerbate the problem. The resulting coastal congestion leads to increasing competition for limited resources, to increased coastal pollution, and to problems related to coastal construction. Technology also allows humans to exploit the reef with mechanical dredges, hydraulic suction, dynamiting, and large-scale poisoning. More specifically, the major causes of coral reef ecosystem decline include:

- The over exploitation of reef resources (fish stocks have declined significantly in many reef areas, especially near centers of human population);
- Excessive domestic and agricultural pollution; and
- Poor land use practices that increase sedimentation.

Millions of people depend on reefs for food and livelihood. Reefs also create sheltered lagoons and protect coastlines and mangroves against wave damage. Mangroves in turn protect reefs from sedimentation and eutrophication. Mangroves and seagrasses also play an important role in coastal protection and provide spawning and nursery areas for reef and offshore fishes.

The economies of many atoll nations are based on marine resources. In the Pacific, over 2.5 million people live on islands built by or surround by coral reef ecosystems. Over 300,000 people live on coral islands in the Indian Ocean and many more in the Caribbean. Coral reefs provide 10–12 percent of the harvest of finfish and shellfish in tropical countries and about 20–25 percent of the fish catch of developing countries. As much as 90 percent of the animal protein consumed on many Pacific islands comes from marine sources (IUCN, 1993). The potential sustainable yield of fishes, crustaceans and molluscs from coral reefs could be some 9 million metric tons – 12 percent of the world fisheries catch. At the present time only a fraction of this potential is realized. Even more important than the actual monetary amount is the people who benefit from these fisheries as they are a major source of income and employment in areas where few employment alternatives exist. Tourism and recreation use of reefs on a large-scale are recent developments. Numerous figures are available describing tourist revenue from coral reefs, but few are clearly defined or comparable. The coral reefs of Florida alone have been estimated to generate some US\$1.6 billion from recreation uses annually. Figures for developing countries are better expressed in other ways – for many Caribbean countries tourism is now the key economic sector, often providing over 50 percent of GNP, and growing very fast. In 1990 Caribbean tourism earned US\$8.9 billion and

employed over 350,000 people. Divers and other special-interest tourists may account for over one-fifth or more of this total. A 1981 Island Resources Foundation coast benefit study of the Virgin Islands National Park found that benefits (US\$23.3 million, of which US\$20.0 million were indirect) were more than ten times larger than costs (US\$2.1 million) – which clearly illustrates the economic benefits of marine protected areas (Dixon, 1993). In Thailand some 5,000 small boat and dive shop operations are dependent on reef tourism (Spencer Davies and Brown 1992). Collecting aquarium fish and live corals for European and North American markets has developed into another lucrative but sometimes damaging industry. Harvesting often kills organisms not intended for collection and more than 50 percent of the fish collected die before reaching market. Tourism can be an environmentally friendly way of generating income from coral reef ecosystems, but only when resort development and operation are carefully controlled. Unlimited collecting, sport fishing, and accidental damage by waders, swimmers and boat anchors can all degrade the reefs that earn tourist dollars. Allowing sewage and other wastes from tourist facilities to pollute reefs or siting resorts so that beach erosion increases, can be even more degrading to the health of the reef than the direct damage caused by visitors.

Information for accurately evaluating the condition of the world's reefs is critical for effective management. However, in many cases this knowledge is lacking. Many countries with coral reef ecosystems need training and capacity building to apply scientific management principles. Non-governmental organizations (NGO's) have and will continue to play a major role in coral reef ecosystem conservation. Since most countries have not incorporated integrated coastal zone management, economic and environmental decision making has not been fully integrated to protect and sustainably use coral reef ecosystems.

The Land-Ocean Interactions in the Coastal Zone (LOICZ) project of the International Geosphere-Biosphere Programme (IGBP) held a meeting in the Philippines from 24–27 April, 1995. A major concern of this international project is determining the role of coastal processes in global climate change. Discussions highlighted the need to better understand coral reef systems, which may play a crucial role in the circulation of CO₂ and other gases. There is a need to better understand human impacts on reef functions, the responses of reefs to changes in sea level, and the interactions between coral reefs and other ecosystems. In particular, more needs to be known about interactions with adjacent land masses, such as through the hydrological cycle. Concern was raised that rising

sea level would have very serious consequences for many nations situated on low, coral reef archipelagos, such as the Maldives. An important workshop on these issues is expected to take place in Japan within the next several months.

Further activities will include the International Coral Reef Symposium (ICRS) to be held in Panama in mid-1996. This is one of a series of symposia held every few years, and serves as a major forum for exchanging information on the science and management of coral reefs, particularly among developing country scientists. The 1996 ICRS will mark the onset of the Year of the Reef. The latter will involve a variety of national and international activities aimed at improving coral reef management. Among the more important activities for which support is being sought will be coordinated surveys of coral reefs around the world, and the establishment of a global coral reef monitoring program. These activities will be extremely important in efforts to determine the status of the coral reefs of the world, and to determine how global changes will affect people dependent on coral reefs.

A project which is specifically designed to provide centralized access to information from these and other coral reef programs is ReefBase: the International Database on Coral Reefs. This project of the International Center for Living Aquatic Resources Management (ICLARM) seeks to gather a broad range of information about the status of the world's reefs from papers, reports and inputs from monitoring projects. The project includes an activity of the World Conservation Monitoring Center to digitize maps of coral reefs and to make them available through the database. The ReefBase project serves as a medium of information exchange for scientists, particularly those in developing countries with limited library facilities, and as a conduit of useful information to coastal planners and managers.

Some initial results of the ReefBase Project are displayed in maps 1 – 6. Each of the maps shows the countries or island states of the world with direct responsibility for coral reefs in dark green, and for less developed coral communities in light green. Maps 1 – 5 (see pages x and x) show the global dispersion of five forms of stress on coral reefs. These maps are not comprehensive, but serve to indicate the scale of each problem.

Stresses on Coral Reefs

Map 1 – Crown-of-Thorns Starfish Outbreaks

The coral-eating crown-of-thorns starfish (*Acanthaster*) has had many outbreaks in the past decade throughout the Indian Ocean and Southeast Asia. The frequency of these often devastating outbreaks may be increasing, possibly a result of human activities.

Map 2 – Bleaching

Bleaching of corals involves the expulsion by the corals of the single-celled algae which normally live in their tissues, and on which they depend as a major food source. Increasing cases of widespread bleaching may be a consequence of global warming.

Map 3 – Sedimentation

A map of sedimentation problems combines effects of increased runoff from deforestation, the dumping of mine tailings, and sediment from a variety of construction projects. Sediment in low amounts reduces coral growth and resilience to stress. In large amounts, particularly during storms, sediment can bury corals or whole coral communities.

Map 4 – Pollution

Pollution is a rising problem, particularly that from urban centers and organic pollution from coastal villages and tourist facilities. Organic pollution often enables seaweed to overgrow coral communities, and there is a need to develop more practical, low-cost methods to reduce this pollution in coastal situations.

Map 5 – Blast Fishing

Blast fishing is widely dispersed and rapidly growing. As with other forms of destructive fishing associated with the condition known as Malthusian over fishing, such as poisoning and muro-ami fishing, the problem tends to increase as human populations increase, resulting in increasingly desperate competition for reef resources. To date more than 40 countries are known to have problems with blast fishing on coral reefs, and more than 15 have reported cyanide fishing.

Marine Protected Areas

Map 6 (page x) shows the marine protected areas covering coral reefs which are currently recognized by the World Conservation Monitoring Center. The size of the dots is misleading, as the total area enclosed by

these reserves and parks is extremely small relative to the coral reef area of the world (less than 1/1000th). There are other protected coral reef areas which do not yet meet the criteria used for this list. However, the total size and dispersion of all protected reefs combined, even if they were effectively managed, is currently inadequate to preserve the biodiversity and fishery production of reefs in any part of the world outside of eastern Australia.

International legal protections and cooperative frameworks for coral reef ecosystems take numerous forms, addressing such problems as coral trade, marine protected area designation and land-based and marine pollution. For example, many, but not all, species of coral are listed in Appendix II of CITES, which requires them to be accompanied by permits for importation. A very limited number of coral reef sites are listed in such treaties the World Heritage and Ramsar Conventions.

2. Human consequences

Degradation of coral reef ecosystems would have significant impact on world food sources, and long-term negative economic impacts on fishery and tourist industries, and a devastating effect on millions of people around the world for whom coral reefs represent the primary source of livelihood.

3. Conclusion

The coral reef ecosystems of the world represent an important resource, both in terms of global biological diversity and with respect to the well-being of the people who live near and depend upon them. Many are at risk and need better management. The future actions of managers, scientists, national bodies, local communities and international programs will be critical in saving these natural treasures.

C. Regional Perspectives

1. Tropical Americas

a. Status and Trends

Coral reef ecosystems in the Tropical Americas (see Map 7, page x) are more numerous in the northern than southern Tropical Americas. Development is restricted on Pacific coasts by cold currents and

upwellings off Southern and Central America: and, on the Atlantic coast of South America by freshwater run-off of major rivers (Orinoco, Amazon). Reefs are best developed on Caribbean coasts. Coral reef ecosystems have been under increasing pressure from expanding human populations since the late 1900's. Under the jurisdiction of about 40 different countries the coastal resources provide important resources for millions of people. Degradation has out paced comprehension of the problems and the ability to deal with them. The extent and accessibility of resources and human densities control the level of impacts. Generally, reefs on narrow offshore shelves suffer intense impact from terrestrial runoff and fishing. Where shelf and reef areas are large relative to the number of fishermen (Bahamas, Belize, Cayman) reef fish are larger and more abundant. Mangrove prefer the low-lying Central and South American coasts but are also found on a smaller scale, throughout the Caribbean (Woodley, in press).

While the reefs of Bermuda are in fairly good shape, sedimentation related to the Bermuda Air Terminal construction caused massive coral mortality, and since 1940, thirteen major ship groundings have destroyed about 1 percent of the outer reefs (Cook et al. 1993).

South Florida and Florida Keys seagrass beds, including those of Florida Bay and along the reef tract, cover an estimated 5, 500 km². In 1987 a massive mortality of seagrasses occurred resulting in the loss of over 40 km². Seagrass mortality has persisted at a lower pace since 1990. A combination of ambient conditions that inhibited the sustainability of the seagrass community and the susceptibility to increased organic loadings from domestic wastes in artificial waterways and dead-end canals within the Keys are possible explanations. Little is known concerning the recent mortality of mangroves but there appears to be a rough spatial correlation with adjacent areas of high salinity in Florida Bay. Evidence is growing that freshwater management practices as far north as Lake Okechobee are having serious effects on coral reef health and coral recruitment (Porter, 1995). Unfavorably warm conditions during long-lasting summer doldrums have been linked to coral bleaching. Add to this equation the four-fold increase in local human population since 1930, impacts from land use (sedimentation), water pollution (point, nonpoint and external sources – eutrophication, leaching of land-based septic systems), boating, recreational and commercial fishing, and the activities of over 3 million tourists a year and you have a coral reef ecosystem struggling for survival. The impacts of fishing are particularly significant because recreational fishing is the area's primary tourist-

related boating activity, and commercial fishing is the fourth largest industry in the region. There are well-documented reports of local declines in coral populations from monitoring, but there is uncertainty about the areal extent of these changes (USDOC, 1994).

The Flower Gardens Banks in the Gulf of Mexico have experienced no significant changes in coral cover, population levels, diversity, evenness, or encrusting growth over the last 20 years. The installation of mooring buoys by the Flower Gardens National Marine Sanctuary has greatly reduced anchor damage (Gittings et al., 1993).

Due to rapid development over the last 50 years most Caribbean reefs are threatened by adjacent densely populated islands. Mangrove depletion has been prominent in the majority of the Caribbean islands including Barbados, British Virgin Islands, Cayman Islands, Dominican Republic, Guadeloupe, Martinique, Netherlands Antilles, Puerto Rico, Trinidad and Tobago, and the U.S. Virgin Islands. Coastal development has had significant environmental impact, through increased turbidity, on the majority of the Caribbean islands. Tourist-related threats include anchoring, littering, trampling, diver damage and over-collection of coral. Both commercial and recreational fishing pressure, as well as destructive fishing techniques, such as fish traps, poison and blast fishing, and spear fishing, have led to significant declines in fish, lobster, and coral populations. Deforestation has led to erosion and increased soil run-off, causing significant siltation of reefs on Dominica, Guadeloupe, Haiti, Martinique, and Puerto Rico. This problem is often aggravated by the input of fertilizers, pesticides, and other agricultural pollutants as is the case in Barbados, Grenada, and Guadeloupe. Less than 10 percent of total domestic waste receives treatment before disposal and much reaches coastal waters, causing eutrophication and accelerated algal growth. Sewage pollution has been reported from Barbados, British Virgin Islands, Cayman Islands, Dominican Republic, Guadeloupe, Jamaica, Martinique, Netherlands Antilles, Puerto Rico, Turks and Caicos, and the U.S. Virgin Islands. Oil terminals/refineries (and associated construction activities), tanker traffic, and offshore oil reserves adjacent to the reefs are also of concern in the Caribbean and the threat of related pollution is most serious in the Cayman Islands, Guadeloupe, Jamaica, Netherlands Antilles, Puerto Rico, Turks and Caicos, and U.S. Virgin Islands. Caribbean coral reef ecosystems also have been afflicted with natural damage due to hurricanes and prolonged algal blooms following the Caribbean-wide mass-mortalities of *Diadema antillarum* in 1983. The lack of herbivory, due to the loss of *Diadema* and chronic overfishing, has allowed algae to

replace coral in many areas, particularly after the coral has been reduced during recurrent hurricanes (IUCN/UNEP, 1988).

As early as 1959 in Jamaica, for example, fish catches in coral reef waters consisted primarily of juvenile fish. Overfishing has removed the grazers on coral reefs and allowed algae to compete with corals for living space. In Jamaica, coral cover dropped from 50–70 percent to under 5 percent after hurricane damage and after disease reduced grazing sea urchin populations (Hughs, 1994). There is still little sign of recovery after ten years.

Coastal waters of Central and South America receive large influxes of freshwater from extensive mainland river systems therefore nearshore reef development is generally poor. However, reefs are found on islands off Costa Rica, Colombia, Honduras and Panama. Belize has the longest barrier reef in the Atlantic with several adjacent atolls. Coastal development which has coincided with the influx of tourism in Colombia, Costa Rica, Honduras, Mexico, Panama and Venezuela is a significant threat to coral reef ecosystems and has resulted in mangrove depletion. Development has increased the amount of raw sewage deposited into coastal waters. Siltation from deforestation has occurred in Brazil, Chile, Colombia, Costa Rica, Mexico, Nicaragua, Panama, and Venezuela and unhealthy water quality has been compounded by herbicide and fertilizer runoff. While reefs play a major role in supporting the artisanal fisheries of Central and South America, recreational spearfishing and over-harvesting of reef resources is of major concern and has led to a decline of fish and coral populations in Belize, Brazil, Colombia, Costa Rica, Ecuador, Mexico, Panama, and Venezuela (IUCN/UNEP, 1988). A combination of natural and human-related effects have produced significant local coral reef ecosystem declines:

Barbados--hurricane damage and loss of urchins that graze on macroalgae;

Colombia off Santa Maria City--pollution and run-off;

Costa Rica--agricultural-related sedimentation; and

San Blas Islands--coral bleaching, loss of grazing urchins, mining pollution, coral mining, sedimentation and eutrophication (Ginsburg, 1994)

In contrast, the Belize Barrier Reef Complex has the largest, most varied, and luxuriant array of reefs in the western Atlantic.

While a management plan was proposed in 1992 for the Galapagos marine reserve, it never took effect. This left a confusing array of responsible agencies and policies that contributed to fisheries conflicts in 1994.

b. Human Consequences

The loss of coral reef resources in this region would have tremendous social impacts relating to loss of work/income and potential problems of loss of an important food source for many artisanal fishing communities. It would also have detrimental effects on the multi-million dollar tourist and fishing industries.

2. Seas of the Middle East

a. Status and Trends

Coral reefs ecosystems in the Seas of the Middle East (Map 8, page 16) are rich, visibly biodiverse and generally in good shape. Large cities and large coastal populations in bordering countries are rare, and human stress to reefs is comparatively low (Ginsburg, 1994).

In the Red Sea, the world's northernmost mangroves live along the southern Sinai coast. Seagrass beds are abundant in the region but their development is limited in areas with steep drop offs and rocky terrain (ISPAN, 1992). The lack of rain and river input allows well-developed fringing reefs to thrive on both coasts of the Red Sea (less in the southern portion). Coral reefs in the Gulf of Aqaba represent the northernmost limit for coral reefs in the Indian Ocean region. Apart from cold weather fronts and extreme low tides, reefs in the region are subject to few natural disturbances. Recently however, northern Red Sea reefs have seen an increase in grazing by the gastropod *Drupella* (Ginsburg, 1994). Rapid coastal development that includes mainly oil related industrial centers as well as tourist resorts pose serious threats to future health of coral reef ecosystems. Inadequate environmental standards in Egyptian and Saudi oil facilities, and the de-ballasting of ships in the Red Sea pose pollution threats to coral reef ecosystems (IUCN/UNEP, 1988).

In the Gulf of Aqaba, pollution from port facilities in Eilat, Israel and Aqaba, Jordan threaten water quality (ISPAN, 1992). Large scale tourism is expected to quadruple by the year 2000. Tourist development impacts can already be seen off Hurghada, Egypt where sedimentation from

coastal development has seriously damaged reefs. The use of imported fine sand for hotel beaches off Dahab threatens these reefs. Eutrophication problems related to nutrient rich sewage water from hotel gardens, as well as desalinization effluents pumped onto reefs from hotels in Quseir and Dahab threaten reef health. Fishing pressure is increasing as the emphasis shifts from sustainable to extractive fishing practices. Lobster are presently over fished around the Sinai. Sharks in the area are reportedly declining for unknown reasons, possibly because of tourist-related activities such as boating. Increased recreational diving will also bring more diver related damage to coral through kicking, trampling or holding, all of which tear the delicate tissues of the corals, increasing the chances of mortality and making the corals more susceptible replacement by algal competitors (Hawkins and Roberts, 1993).

The reefs of the north and south regions of Yemen and Oman are beautiful, but are under constant threat from oil pollution. Although development is increasing, human stress is minimal because coastal populations are relatively small.

In the Arabian Gulf, the extent of mangroves has been declining due to the impacts of unplanned coastal development, with only about 125–130 km² remaining (90km² off Iran, 10 km² off Gulf coast of Saudi Arabia and Bahrain, remainder along the UAE coast). In Saudi Arabia more than 40 percent of the Arabian Gulf coastline has been infilled and 50 percent of the mangroves lost. Seagrasses occur principally in shallow (< 10 m) coastal areas and form the basis for many food chains. More than 530 species of plants and animals were recorded among seagrasses in the Gulf. Approximate figures from Tarut Bay (410 km²) suggest these seagrass beds support production of 2 million kg of fish annually at a 1987 value of US\$10 million, or the same quantity of shrimp worth US\$12 million (Price, et al., 1993). Coral reefs occur mainly as numerous patch reefs. However, fringing reefs are found around offshore islands. Coral diversity is low compared to the Red Sea (55–60 species vs. nearly 200 in the Red Sea). High and low water temperature and high salinities affect coral species diversity and many species live near their maximum tolerances. Immediate impacts from oil spills during the Persian Gulf War were less than generally expected, indicating a high resilience among reef communities in this area. However, continued monitoring is needed to reveal longer term effects (Downing and Roberts, 1993). Oil, domestic, urban, and industrial pollutants are a problem in several parts of the Arabian Gulf, although effects on ecosystem structure and function are

generally not well known. The coastal zone is fast becoming the repository for solid wastes. Major ecological problems have arisen from loss/degradation of productive coastal habitats, caused by landfill, dredging and sedimentation. Anchor damage to coral reefs is a problem on Jurayd Island and possibly elsewhere. Fishing pressure is intensive in some areas (Price, 1993).

b. Human Consequences

There are enormous differences among countries regarding the effects of lost coral reef resources in this region. Some countries (Egypt, Israel, Jordan) would lose enormously from the loss of tourist revenues where others (Saudi Arabia, Sudan, Eritrea, Iran, Qatar, Yemen) effectively have little tourism but would suffer from the loss of commercial and artisanal fisheries.

3. Indian Ocean

a. Status and Trends

The Indian Ocean region is a large biologically diverse area bordered by many countries (Map 9, page 18). Regional human population growth is a major threat to coral reef ecosystem health as many reefs are located near large population centers. It is estimated that over 20 percent of the coral reefs and five percent of the seagrass beds have been destroyed (IUCN/UNEP, 1985). The use of illegal fishing methods (dynamite, poisons, intoxicants) is widespread (IUCN/UNEP, 1988). Few scientific studies exist to document the extent of damage.

In East Africa total mangrove area is about 600,000 – 1,200,000 ha, and distribution is correlated with coastal indentation and large river discharge. Over-exploitation and the lack of expertise and institutional management capacity threaten their existence. Seagrass beds are found throughout the region and are under pressure from intensive use of bottom traps and beach seines, explosives fishing, sand mining and dredging (GBRMPA et al., in press). Coral reefs are important sources of food for local human populations and are of major commercial importance for fisheries and tourism. The Somali coast has few reefs due to seasonal cool upwelling and those that do occur are not well developed (except for southern coast and adjacent Bajuni Islands where reefs are well developed). Some patch reefs occur off Mogadishu. Well developed fringing and patch reefs occur off Tanzania, are close to shore,

and are only discontinuous where large rivers meet the sea. Reefs are also found around Mafia and Zanzibar Islands. Reefs off Kenya and Mozambique have similar limitations. Extensive reefs of all types exist off Madagascar. Mauritius, Reunion and Comoros Islands also have fringing reefs. Small fringing reefs are most common around the Seychelles Islands along with a few atolls such as Aldabra where reef formations are spectacular. Overexploitation of fishery resources has been reported from Tanzania and Mauritius, and reefs off Kenya, Tanzania and Mauritius suffer from destructive fishing practices. Trampling of coral by fishermen have also degraded reefs in the region. Coral and coral sand mining in Mafia (Tanzania), Comoros, Mauritius and Madagascar has damaged reefs. Over 500,000 tons of coral sand are excavated annually from Mauritius and most beaches in Comoros have been scarred by sand mining. Over 250 tons of shells and corals were exported from Tanzania in 1974. Exploitive collection has moved from the depleted areas off Tanzania and Kenya to the islands of Zanzibar and Mafia. Sedimentation from agricultural practices is a major problem throughout the region. The problem is critical in Comoros and has also affected reefs off the Seychelles, Dar es Salaam and Zanzibar. Eutrophication is a problem in Port Louise, Dar es Salaam and Zanzibar (Mohammed, 1994).

The northern Indian Ocean is divided by India, forming the Arabian Sea and the Bay of Bengal. The Bay of Bengal, the Sunderbans and the Ganges delta support over 500,000 ha of mangrove. India supports about 100,000 – 700,000 ha. Mangroves are not as abundant in Sri Lanka (10,000 – 12,000 ha) and are patchy in the atoll islands of the area. Mangroves are economically very valuable in the area and are used heavily. Since 1963 about 50 percent of India's mangroves have been destroyed. Extensive seagrass beds are found in southern India and in the many estuaries of Sri Lanka where they cover an area greater than that covered by mangroves and coral reefs, make the largest contribution to primary productivity in coastal waters and support over 50 percent of the countries coastal fishery production. The degree of exposure and water turbidity limit the extent of seagrasses in western India and populations are negligible off Bangladesh because of seasonal fluctuations in salinity. Seagrasses are also limited off the Maldives (GBRMPA et al, in press). Most coral reef growth is inhibited by fresh water and sedimentary deposits from rivers. Bangladesh and Pakistan lack reefs although there are isolated colonies. There is relatively poor reef growth on the west coast of India, mainly in the Gulf of Kutch. Reef growth becomes more vigorous towards the southern tip of India and around the coast of Sri Lanka (Wells, 1993). Like the East African region, countries such as

Myanmar, Thailand, India, and Sri Lanka suffer from over-fishing/shelling, tourism, mining, and industrial growth (IUCN/UNEP, 1988). Sri Lanka has been especially prone to over-exploitation as over one third of the population lives in coastal areas and on average 65 percent of the national animal protein comes from marine sources (almost 100 percent for coastal areas). Coral mining is especially serious in the Maldives (used for road construction), Sri Lanka, and India where tens of thousands of tons are removed annually. Deteriorating fish populations force fishermen to travel further to find productive spots and the aquarium fish industry threatens populations off Sri Lanka and the Maldives (Öhman et al, 1993).

Most reefs in the eastern Indian Ocean are found offshore. Chagos, a group of coral covered banks, reefs, atolls and fringed coralline islands, is located in the central part of the Indian Ocean and contains the best developed, most pristine, and greatest variety of reefs in the Central-Western Indian Ocean. Some of the reefs at Diego Garcia have been affected by dredging for construction associated with the large military presence.

b. Human Consequences

Coral reef ecosystem degradation would have serious impacts on food supply for local inhabitants and major economic impacts for the fishing, aquarium, and tourist industries.

4. East Asian Seas

a. Status and Trends

The region (Map 10, page 20) is unique in its abundance and variety of reefs and for the fact that it is at the center of coral reef ecosystem biodiversity. Mangrove is the dominant coastal community (at its diversity peak), supports over 100 seabird species, and provides breeding and nursery areas for fish and shrimp. The most diverse seagrass flora – about 20 species – in the world is also found in the region. Economically and environmentally important, seagrasses form dense beds, cover large coastal areas, provide habitat and nursery areas and are sources of food for many organisms (GBRMPA et al., in press). They also support millions of coastal villagers who rely on them for a wide variety of useful products. Over 30 percent of the worlds coral reefs are found in southeast Asia alone. Rapid economic and human population growth –

over 440 million for peninsular and insular SE Asia, with the population doubling in the next 25–35 years – and severe local coral reef ecosystem degradation also characterize the region. Coral reef ecosystems in more remote areas are probably in better condition. People extract about 60 percent of the regions' animal protein of food from the sea. Major stresses include: organic and inorganic pollution, sedimentation, and overexploitation. For these reasons it is estimated that most of the reefs will be severely depleted within the next 40 years (Wilkinson et al., 1993).

In Southeast Asia (SEA), Vietnam has over 200,000 ha of mangrove and cover has decreased about 45 percent since 1945. Brunei has about 7,000 and Cambodia about 10,000 ha (GBRMPA et al., in press). Few reefs exist off Brunei Darussalam, Cambodia, and Vietnam because of high coastal turbidity. Few of the offshore reefs have been studied. Reefs off Brunei are rich in coral and fish species as fishing pressure is low. The best Burmese reefs occur near the Thailand border where river effects are low. Reefs of the Mergui Archipelago are in good shape although many of the larger reef animals (turtles) are exploited. Reefs off Vietnam have been damaged extensively by sedimentation, as well as by blast and cyanide fishing (Wilkinson et al., 1993).

Indonesia, with its 81,000 km of coastline and over 17,000 islands, is of critical importance as the center of coral reef ecosystem diversity (Wells, 1993). It has a large amount of mangroves (4.25 million ha) and those in the western part of the country have suffered from illegal cutting, coastal development (about 300,000 ha lost) and land-based pollution. Over 1 million hectares have been designated for use as "production" forest. Mangroves in the east are less impacted. Coral reefs in Indonesia are extensive and represent the most significant reef resource in southeast Asia. Reef conditions vary. Off Java and Sumatra reefs are damaged from overexploitation, sedimentation, and organic pollution. To the far east and northeast, reef ecosystems are in excellent shape – particularly those which are relatively inaccessible to coastal dwellers. In central Indonesia reefs are degraded from blast fishing, cyanide fishing and overfishing/collecting. Population pressures are lower on eastern Indonesian reefs and if destructive fishing is controlled, many damaged reefs in this area may recover. Human population growth and associated forest clearing and sedimentation are expected to severely affect reef health in western Indonesia. Coral reef ecosystems of Palau Seribu, which provide fishery resources for Jakarta and tourist opportunities, are being severely impacted by mainland pollution and overfishing (Wilkinson et al., 1993).

Malaysia has 650,000 ha of mangroves. Coral reefs of Malaysia suffer from organic and sediment pollution and overexploitation, but not as much as in other regional countries. Construction related sedimentation has impacted the reefs in the Palau Redang marine reserve. All reefs in the Peninsula Malaysia region are expected to decline significantly in the next 20 years as a result of sedimentation and water pollution. Reefs off Sabah are experiencing overexploitation (Wilkinson et al., 1993).

Over 80 percent of the mangroves in the Philippines have been lost since the 1920's leaving only about 100,000 ha – half of which consists of secondary growth. The largest and most pristine stands are off Palawan and Mindanao Islands. Reefs are in decline throughout the Philippine Archipelago due to blast and cyanide fishing, muro-ami fishing (involving the use of weights on ropes to smash corals and drive fish into nets), sedimentation, port construction and eutrophication. Coral cover is rapidly declining. Fish populations are low from overfishing. The loss of 80 percent of the mangrove area and more than half of the total forest area since 1920 has stressed reefs with sedimentation and caused fish populations to decline. Large areas of Scarborough reef off Luzon and other large, offshore reefs has been denuded of fish and coral from blast and muro ami fishing within the last 2 years (Wilkinson et al., 1993). Between 1966 and 1986 the productivity of coral reefs in the Philippines dropped by one third as the national population doubled (McAllister, 1988). The Philippines is the major exporter of coral for displays and aquariums, despite being prohibited within the country and by the states where tourists import them. Giant clams have recently been added to the list of species covered by the Convention on International Trade in Endangered Species (CITES) as a means of reducing the trade.

The coral reefs of Singapore are valuable ecotourist destinations, however, they are being severely degraded by construction of port and oil processing facilities and other coastal development. Coral cover is high on the outer reefs and reduced (<50 percent) on nearshore reefs. Heavy sediment loads limit coral distribution to < 10 m depth. Fish and coral collecting for the aquarium trade are also threats (Wilkinson et al., 1993).

From 1979 – 1987 mangrove cover has been reduced by 25 percent in Thailand and the remaining 196,000 ha (Aksornkoe, 1993) are under stress from farming, mining, salt farming and coastal construction. Thailand's nearshore reefs are suffering from coastal development while offshore reefs have relatively high coral cover. Domestic and industrial

pollution from Bangkok and Pattaya have almost totally destroyed the reefs in the northern Gulf of Thailand. Reefs off the western coast of the Gulf are in better shape with coral cover often exceeding 50 percent. However, recent reports show that coral cover is declining by 20 percent annually due to tourist related coastal clearing and sewage pollution. Healthy reefs with over 75 percent coral cover can be found in the Andaman Sea off Smilan and Surin Islands. Off Phuket, reefs are being stressed by overfishing, tourist activities and the release of sewage and sediment into shallow Phangnga Bay. The Gulf of Thailand fishery is close to collapse (Wilkinson et al., 1993).

Off China, mangroves are threatened by agricultural land reclamation, construction of dikes for aquaculture and by firewood cutting. Coral communities are found mainly around offshore islands and archipelagos in the Nan Hai. The most important reef areas are south of Hainan where reefs suffer from overfishing and siltation. Coral mining, dredging and collecting for the aquarium trade also impact reefs. Mangroves are threatened by agricultural land reclamation, construction of dikes for aquaculture and by fire wood cutting (IUCN/UNEP, 1988).

Off Hong Kong there are no true reefs however, about 49 species of corals grow on hard bottom along the eastern and southeastern coasts and in certain ocean areas. Coral growth in central Hong Kong is impossible because of urban, industrial and agricultural pollution, while land reclamation, overfishing/collecting, and visitor use threaten corals and mangroves in the northeast. Reefs in the east suffer from land reclamation, dumping of dredged materials and sewage discharge (IUCN/UNEP, 1988).

Except for the sandy west coast, coral reef ecosystems are found all around Taiwan and have magnificent soft coral coverage. Tourist abuse, aquarium fish collecting, sedimentation from construction and dredging, explosive fishing, coral collecting and various types of pollution threaten many reefs (IUCN/UNEP, 1988). Taiwanese harvesting of giant clams has led to local extinctions.

Off the many Islands of Japan, coral-eating crown-of-thorns starfish (*Acanthaster*) infestations and coral bleaching have affected some reefs. Deforestation, agricultural development, dredging, coastal construction, tourism, and reef gleaning are growing threats. In Okinawa, sedimentation from coastal construction and agriculture has dramatically decreased coral cover (IUCN/UNEP, 1988).

b. Human Consequences

Coral reef ecosystem degradation would significantly limit food supplies to growing populations and would devastate commercial fishing and tourist industries.

5. Pacific

a. Status and Trends

The Pacific region (Map 11, page 23) has an extremely diverse selection of mangroves, seagrasses and coral reefs and is the largest region of coral reefs in the world's oceans. There are extremes in the condition of coral reef ecosystems and in the extent of scientific information about them. In the Pacific Islands there are about 146,000 ha of mangroves (about 0.7 percent of the world population), the largest areas occur in Solomon Islands, Fiji, and New Caledonia (Ellison, in press). Many mangroves have been lost to land clearing, agricultural development, and construction and many suffer from pollutants such as oil spillage, contamination from heavy metals and hazardous wastes, and run-off (Scott, 1993). Seagrasses are usually found in water less than 10 m but can be found at depth of 50 m. They live in nutrient rich muds adjacent to mangrove fringes, in carbonate sands around cays on coral reefs and colonize coral reef platforms and exposed reef slopes. There is a lack of published seagrass research, apart from taxonomic, available for the region. Standing crop biomass is relatively low and little is known on how biomass values change seasonally (Coles and Long, in press). Overall, the condition of coral reefs in the Pacific was rated to be about 70 percent excellent to good and about 30 percent fair to poor. Reefs removed from centers of human population i.e., most of the Australian Great Barrier Reef, atolls in Papua New Guinea, the Caroline and Cook Islands are in the best of shape (Ginsburg, 1994).

To summarize some of the problems, the region will be divided into five areas: Melanesia, Micronesia, Polynesia, Australia and New Zealand. In Melanesia, coral reef ecosystems in the Solomon Islands have very high biodiversity and most are in excellent condition. Upland mining, logging and coastal development are potential threats. Much of the 64,200 ha of mangroves are being impacted by land clearing and commercial logging. Irian Jaya and Papua New Guinea have some of the largest unbroken stretches of mangroves in the world, thousands of uncharted islands and

reefs, and is one of the most biodiverse parts of the world. Although the reefs are virtually pristine, many are coming under increasing threat from soil erosion related to land clearing for logging and mining and from the discharge of mine tailings. New Caledonia is the third largest of the Melanesian and insular Pacific island groups. Land erosion caused by mining and bush fires is slowly affecting the reefs, as is sewage discharge, industrial pollution and overfishing. The island region of Vanuatu consists of 42 volcanic islands with the larger islands consisting of extinct volcanoes with uplifted coral reefs. Human-related stresses are confined to the urban center of Port Vila on Efate where overharvesting of corals, coastal construction and possibly sewage discharges are degrading reefs. Finally, in the over 840 different islands that make up Fiji, natural disturbances such as earthquakes and tropical cyclones disturb the reefs. In the Suva urban area, soil erosion from logging and upland farming, disposal of tailings from copper mines, sand dredging for construction materials and pollution stress reef ecosystems. Overfishing and overharvesting are degrading reefs near population centers, and giant clams have been seriously depleted. Traditional fishing controls are still exercised by villages (Maragos and Holthus, in press).

In Micronesia, the Mariana Islands are volcanic in the north, and are a mixture of larger high limestone and volcanic islands in the south. Much of the poor reef development is due to natural factors such as volcanoes, earthquakes, and tropical cyclones. On Guam, soil erosion and sedimentation from military, resort and residential development stress corals. Near urban centers and Apra Harbor coral reef ecosystems are degraded by sewage, thermal discharges and port construction. In some areas tourist impacts are evident. Overfishing and overharvesting are also problems off Guam, Saipan, Tinian and Rota. The Caroline Islands are composed of 22 groups of high volcanic and limestone islands, and low coral islands. Natural disturbances to the coral reefs are from typhoons, and large wave action. Human threats are beginning to affect the coral reefs and include urban pollution, overfishing, sewage discharge, and the overharvesting of shellfish. Soil erosion and sedimentation from resort and transportation projects are the greatest threats to coral reef ecosystems around Belau. The Federated States of Micronesia (FSM) consist of 4 high volcanic islands around 31 atolls and 7 low coral islets. There is internal FSM migration and population growth, urban pollution such as sewage and garbage disposal is increasingly becoming a problem. However, since integrated coastal zone management is nascent, there are no marine protected areas. Construction of roads, ports and airports have

degraded several reefs and overcollection and overfishing of various marine species is becoming problematic. Tourism, with its associated impacts, is a developing industry, catering mostly to sport divers. The Marshall Islands consist of low coral islets resting atop 29 atolls and 5 table reefs. Tropical cyclones naturally disturb the coral growth within the area but serious anthropogenic threats are present. Mining, residual damage from nuclear testing, sewage discharge and construction have impacted some reefs. Recent construction north of Ebeye has degraded reefs. The Republic of Kiribati is southwest of the Marshalls. Besides natural stresses such as cyclones, human impacts are slowly taking their toll. Urban pollution and construction near Tarawa, as well as overharvesting and inadequate treatment of discharged sewage are likely degrading reefs. The Republic of Nauru is very narrow with fringing reefs encircling the island. Human impacts are minimal. (Maragos and Holthus, in press).

In Polynesia, Hawaii is located in extreme geographic isolation. Natural disasters such as heavy wave action, cyclones and earthquakes disturb coral reef growth. Land clearing, agricultural development, dredging, overfishing, and tourism are some of the human factors which effect reefs. There is no comprehensive monitoring program in place to better assess the causes and consequences of coral reef ecosystem decline. The waters surrounding American Samoa are mainly dominated by fringing reefs. Crown-of-thorns starfish infestations in the late 1970's and more recent devastating storms have reduced live coral cover below normal levels. Results of recent surveys show reefs are in poor condition except for those off Olosega Island and Rose Atoll. Reef fish populations are depleted and industrial pollution has further degraded the coral reef ecosystem in Pago Pago Harbor. The volcanic islands of Western Samoa are mostly surrounded by fringing reefs. However, much of the reef development is interrupted by constant wave action and lava flow. Some reefs in Western Samoa are affected by the agricultural industry, mining, construction, sewage and overfishing and exploitation. The Kingdom of Tonga has 174 island and reef systems sub-divided into four north-to-south groups. Low tides, cyclones, and Acanthaster infestations affect the reefs. Pollution, causeway construction, destructive fishing techniques, sewage, tourism, and the overcollection of shellfish have degraded reefs in certain areas. French Polynesia consists of several island groups, totaling 116 separate islands and atolls. Three-fourth of the human population lives in the Leeward (Society) Islands. Severe tropical storms are disturbing and inhibiting coral reef growth.

Since the population is steadily growing, many marine resources are becoming over-taxed. Overfishing, dredging, filling, construction, sand mining, sewage, industry, and nuclear testing are detrimental factors in certain areas. The Cook Islands are disturbed naturally by tropical cyclones. Most human stress to coral reef ecosystems (construction, land reclamation, and sand mining) are around the urban center of Rorotonga. Airport, hotel and port construction have contributed to soil runoff and degraded some reefs. Tuvalu is a region consisting of low coral islands. The major source of natural disturbance is tropical storms. Islands are extremely small and are dependent on the fishing and shellfish industry. Human stress (overharvesting and some water pollution) to reefs is limited to the heavily populated Funafuti Atoll (Maragos and Holthus, in press).

Coral reef ecosystems of the Great Barrier Reef removed from human populations off Eastern Australia are healthy (Ginsburg, 1994). However, coral reefs near the coast, where over 85 percent of the coastal catchment area is under agricultural development, are being adversely affected by eutrophication (Bell and Tomascik, 1993).

Coral communities around the islands of New Zealand are not under much stress naturally or anthropogenically. The only potential threat is the growing problem of over-fishing, especially for spotted black grouper (IUCN/UNEP, 1988).

b. Human Consequences

The loss of coral reef resources in this region would have detrimental effects on the tourist and fishing industries. In addition, the exploitation of coral reef resources by foreigners could harmfully impact indigenous cultures who are closely tied to and dependent upon local coral reef resources.

[Note to Readers: This chapter does not attempt to summarize the various Regional Reports prepared for the workshop. Some are still in the process of revision and may be further revised after the regional workshops, at which time final copies of the reports will be made available.]

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FOOTNOTES*****

{1}1. Chapter excerpted from Jameson, S.C., J.W. McManus and M.D. Spalding. 1995. State of the Reefs: Regional and Global Perspectives. International Coral Reef Initiative Executive Secretariat Background Paper, US Department of State, Washington, DC, 32 p. For copies of the complete paper contact Stephen C. Jameson, US Department of Commerce, National Oceanic and Atmospheric Administration, Office of Ocean and Coastal Resource Management, 1305 East-West Highway, Silver Spring, MD 20910, USA.