GCRMN

GLOBAL CORAL REEF MONITORING NETWORK

Status of Coral Reefs of the World: 1998

Edited by Clive Wilkinson

AUSTRALIAN INSTITUTE OF MARINE SCIENCE

Published on behalf of the Global Coral Reef Monitoring Network by the Australian Institute of Marine Science

Dedication

This book is dedicated to the President, Vice-President, the Government and People of the United States of America for their concern for the coral reefs of the world and for their foresight in establishing the International Coral Reef Initiative and supporting the Global Coral Reef Monitoring Network.

Postal addresses:

PMB No 3
Townsville MC QLD 4810
Australia

PO Box 264
Dampier WA 6713
Australia

Telephone: (07) 4753 4444 (08) 9183 1122
Facsimile: (07) 4772 5852 (08) 9183 1085
World Wide Web: http://www.aims.gov.au

National Library of Australia Cataloguing-in-Publication data:

Status of coral reefs of the world : 1998

ISBN 0 642 32218 X

1. Coral reefs and islands. I. Wilkinson, Clive R.
II. Australian Institute of Marine Science.

578.7789

FOREWORD

Coral reefs are particularly important to millions of people around the world as sources of high quality protein, medicinal, and cultural products. They also provide raw materials for dwellings along the coast, and protect fragile shorelines from storm damage and erosion. Many economies are also dependent on reefs and their products. The coral reefs, and the white sand beaches they produce, are worth hundreds of million of dollars in tourism to some tropical countries, and are the mainstay of many small island developing states. Lobster, conch, snapper, and grouper are increasingly in demand by thriving tourist industries as well as the international seafood market.

Coral reefs are also of great value to the world at large as they are the hotspots of marine biodiversity. For example, a small coral reef in Indonesia may support over 300 species of corals, 700 species of fish, and many thousands of other animals and plants.

But in the early 1990s, alarm calls were sounded from all quarters — the reefs of the world were in serious trouble, with large-scale degradation occurring in East Africa, South and Southeast Asia, parts of the Pacific, and across the Caribbean. These calls were made up of a series of individual reports of reefs being damaged by human activities, or often by a combination of human and natural stress, but there were no clear assessments documenting the status of reefs around the world. Thus came a response by governments, donor agencies, and the scientific community to set up global monitoring programs that could help decision makers and the public evaluate the health of the world's reefs.

In 1994, the government of the USA stimulated the formation of the International Coral Reef Initiative (ICRI), and a subsequent Framework for Action, which included the establishment of a Global Coral Reef Monitoring Network (GCRMN), which has produced this book. About this time, the International Center for Living Aquatic Resources Management in Manila (ICLARM), a member of the Consultative Group for International Agricultural Research, set up a global database — ReefBase. Subsequent monitoring efforts include Reef Check, a rapid assessment technique which developed out of Hong Kong, and AGRA, a regional initiative for the Gulf of Mexico and the Caribbean. It is very pleasing to note that these programs are

not simply research oriented, but are designed to provide resource managers with the type of information they need to make wise decisions for reef conservation.

The World Bank also recognised the importance of coral reefs to its clients, as a global public good under increasing threat from unsustainable development. The Bank, in partnership with the Global Environment Facility and others, is currently supporting the preparation and implementation of a growing portfolio of coral reef conservation and management projects around the world. These include national projects in Indonesia, Madagascar, Mauritius, the Seychelles, Egypt, India, and Mozambique, and regional initiatives in Mesoamerica and the Red Sea. The World Bank has also been a strong supporter of the International Coral Reef Initiative since its inception, and is now pleased to be a co-sponsor of the GCRMN.

I welcome this summary report on the status of the world's reefs, and urge you to join in supporting efforts such as these to understand not only the physical dimensions of coral reef integrity and health, but the social and economic aspects of how we affect and are affected by the health of these vital marine ecosystems. As we know, the threats to coral reefs from all quarters are increasing. The following report summarizes the unprecedented massive coral bleaching event that occurred during the El Niño-La Niña ocean current oscillations of 1997–1998. From the information provided by this and other monitoring efforts, we can begin to develop a critical baseline against which to monitor trends and evaluate our attempts to introduce better management of reef resources. Only in this way can we hope to reverse the degradation that threatens the very existence of coral reefs and preserve for future generations the contemplation of these natural wonder.

Ismail Serageldin 19 October, 1998
Vice-President, Special Programs
The World Bank

CONTENTS

ACKNOWLEDGEMENTS

The production of this book had a gestation period of more than three years. At the International Coral Reef Initiative meeting in Dumaguete, Philippines in May-June 1995, a call was made to form the Global Coral Reef Monitoring Network (GCRMN) and one of its tasks was to produce a report on the ecological condition of coral reefs for international forums. This is the first of those reports. In June1996, Bernard Salvat (EPHE University of Perpignan, France) and I organised a session at the 8th International Coral Reef Symposium in Panama at which many of these papers summarising the status of coral reefs were presented and most were published in the proceedings.

The authors who contributed then, and have since assisted in editing and updating the essays, are specially thanked — without them there would be no volume. Some of the essays required considerable reworking to fit into the style of this book, and this has consumed much of the authors time — thank you.

The GCRMN has four co-sponsors. Particular thanks go to Patricio Bernal, the Executive Secretary of the Intergovernmental Oceanographic Commission of UNESCO, and George Grice, who have been major supporters of the GCRMN and have assisted in many administrative and policy matters. The United Nations Environment Programme and Agneta Nilsson have provided strong advice and financial support, and help has been obtained from some regional offices of the World Conservation Union (IUCN in Nairobi and Colombo). Recently the World Bank joined as a co-sponsor, and Ismail Serageldin, Marea Hatziolos and Andy Hooten gave strong moral support and advice prior to this.

The major financial support to keep the GCRMN going has come principally through the help of Peter Thomas, of the Department of State, and Arthur Paterson, of the National Oceanographic and Atmospheric Administration of the US Government. These agencies have provided most of the financial support for the Network, along with a considerable contribution from my home institution, the Australian Institute of Marine Science.

The donors of funds for the production of this volume listed on the inside cover and back cover are specially thanked, as their generosity has enabled us to distribute this book at no charge. Particular thanks go to those people who acted as their agents: Bernard Salvat on behalf of EPHE and Naturalia et Biologia; Ismail Serageldin, Marea Hatziolos and Andy Hooten for the World Bank; Lynne Hale of CRC, University of Rhode Island and USAID; Steve Colwell on behalf of CORAL — The Coral Reef Alliance; George Grice on behalf of IOC/UNESCO; and Olof Linden on behalf of the Swedish International Development Cooperation Agency (Sida) and Swedish Agency for Research Cooperation with Developing Countries (SAREC).

The Director (Russell Reichelt) and staff of the Australian Institute of Marine Science are thanked for providing considerable advice on coral reefs and monitoring, and for the production of this book, especially Terry Done, Hugh Sweatman and Will Oxley. The Director General of ICLARM (Meryl Williams) and John McManus and the team in ReefBase have given great support and provided data for many of these essays.

Most importantly, I wish to thank those wonderfully helpful and patient people in AIMS Science Communications: Sandra Child, Steve Clarke, Wendy Ellery, and Tim Simmonds. Sandra was particularly helpful as an editor, correcting many little flaws of scientific jargon under high pressure of deadlines. Janelle Lane made an excellent job of the maps.

Last, but not least, special thanks go to Bernard Salvat and George Grice who are the two main advisors for the GCRMN, and who both provide almost day-to-day assistance, and to Madeleine Nowak who kept me sane when I was putting this together.

Clive Wilkinson
Australian Institute of Marine Science

INTRODUCTION

RUSSELL REICHELT, MERYL WILLIAMS AND PATRICIO BERNAL

In 1996, at the International Coral Reef Symposium in Panama City, Clive Wilkinson and Bernard Salvat organized a symposium to summarise the status of the world's coral reefs. Leading coral reef scientists with direct experience of the condition of reefs in many parts of the world presented summary statements about reef regions and these were published in the symposium proceedings. The scientific papers presented at the symposium have been summarised and updated for this booklet which aims to inform the public, decision makers, international agencies, and the media about the current status of coral reefs around the world. Since the Panama meeting, coral reefs of the world have been seriously impacted by a major coral bleaching event in 1997 and 1998. A summary of this event is included, listing the countries affected.

The Global Coral Reef Monitoring Network (GCRMN) is producing this book to provide an up-to-date summary of reef status for the International Tropical Marine Ecosystems Management Symposium in Townsville, Queensland, in November 1998. The GCRMN was established in 1995 at a meeting of the International Coral Reef Initiative held in the provincial town of Dumaguete in Southern Philippines with over 35 countries present. The GCRMN aims to promote regional networks for gathering consistent information about coral reefs so that governments will be better aware of the state of these valuable resources. This Network is hosted jointly by the Australian Institute of Marine Science (AIMS) and the International Center for Living Aquatic Resources Management (ICLARM). ReefBase, the global database for the GCRMN is hosted by ICLARM.

Coral reef research has been a major theme of study at AIMS since it started in 1972, and AIMS has established itself as a centre for the development of marine monitoring methodology. The methods used by the GCRMN were developed by AIMS in collaboration with scientists from five ASEAN countries (Indonesia, Malaysia, Philippines, Singapore, and Thailand) during the ASEAN-Australia Living Coastal Resources Project from 1984 to 1994. Copies of the methods manual (English, S., Wilkinson, C., Baker, V., 1997, Survey Manual for Tropical Marine Resources, 2nd Edition, Australian Institute of Marine Science, Townsville, p. 390) are available through the AIMS home page: www.aims.gov.au.

ICLARM has an active program of research and training on the use, health, monitoring, and management of coral reefs, with an emphasis on those in developing countries. Coral reefs are fragile but productive ecosystems on which millions of poor people in developing countries depend. As part of its international review activities, ICLARM and the World Resources Institute, the World Conservation Monitoring Centre and the United Nations Environment Programme recently conducted a model-based assessment of the degree of threat to selected coral reefs around the world. The report of this study, Reefs at Risk (Bryant et al. 1998) is recommended as a complement to this volume of empirical scientific studies on reefs.

International coral reef initiative and the Global Coral Reef Monitoring Network

AIMS is a supporter of the International Coral Reef Initiative and hosts the Global Coral Reef Monitoring Network (GCRMN) at its headquarters in Townsville. AIMS is able to provide both logistical and financial support in monitoring methodology, data analysis, and for publications, and we are happy to assist in the production of this book. Members of the AIMS Long-Term Monitoring Project have provided training in monitoring methods for the GCRMN in several countries of the Pacific and southeast Asia (Cook Islands, Tonga, Saipan, Palau, Papua New Guinea, Vietnam). The GCRMN is also supported by the government of the USA through grants to the Intergovernmental Oceanographic Commission (IOC) of UNESCO and the United Nations Environment Programme.

AIMS is also involved in long-term, large-scale monitoring of Australia's Great Barrier Reef and reefs of northwestern Australia. This information is made directly available to the major management agencies for Australian reefs: the Great Barrier Reef Marine Park Authority and Western Australia's Conservation and Land Management Department.

AIMS and ICLARM recognise that different levels of monitoring are required to obtain data and information on the thousands of coral reefs spread across the tropical and subtropical oceans. There are just too few scientists available to visit more than just a few of these reefs, and detailed scientific monitoring is both time consuming and expensive. Indeed it is becoming harder to find money for coral reef monitoring in these difficult financial times. Thus the approach of the GCRMN is to encourage reef monitoring by communities and volunteers, and governments and institutions in the developing world.

The GCRMN is focussing on monitoring by governments in developing countries around the world. It is doing this by establishing networks of adjacent countries and by providing the networks with training and basic equipment. A critical role is to search for funds to run these networks. To date, the European Union and the Governments of the UK and Sweden

have provided funds for networks to get started. These networks are also assisted by research scientists in these countries and others nearby to provide the training and assistance in data analysis and report writing.

The GCRMN has combined with Reef Check out of Hong Kong to cover the community and volunteer level monitoring. Reef Check has only been established for two years, but it has galvanised hundreds of volunteers, who work with coral reef scientists to assess hundreds of reefs in over 40 countries. The Reef Check network is being expanded to provide communities around the world who want to assess and manage their own coral reefs with the basic methodology.

The GCRMN has two distinct goals: gathering information on the status and trends in coral reefs around the world; and raising awareness amongst those who do the monitoring and receive the information on the need for immediate action to reduce the damaging impacts of human activities. The data will be contributed to the Global Ocean Observing System (GOOS) of the IOC to construct models of coastal ecosystems.

The awareness-raising goal is particularly important as most reefs are so remote that only adjacent communities have the capacity to implement surveillance and direct management to stop damaging practices. These communities in turn will put pressure on governments to implement better regulations to prevent damage from pollution and sediment flow resulting from poor land practices, such as clear-felling of tropical forests. Over-fishing is another major threat, particularly when the fishing is done with cyanide poison and dynamite.

This is the strength of the partnership between AIMS and ICLARM: AIMS is a scientific institute that is focussed on gathering data on tropical marine ecosystems; whereas ICLARM seeks to work with peoples of the developing world to improve their livelihoods, through wise use of their resources and through promoting aquaculture and sustainable development.

The goal of this book is to make the information from leading scientists available to a wide audience outside the scientific community. It gives the latest summary of coral bleaching gathered from contributions on the internet and through e-mail listings. Many reefs around the world have been seriously damaged by bleaching over the last 12 months, but there is also evidence that large areas of the world's reefs have not been impacted at all.

We welcome this summary report on the status of the world's reefs. This report will constitute a baseline against which we can measure our attempts to introduce better management of reef resources in the future. The recent bleaching event demonstrates that

long-term monitoring data are essential, as many reefs around the world have already been severely impacted by natural impacts and direct and inadvertent human activities. It will be critical to follow-up the bleaching to determine whether bleached corals are able to recover and whether reefs can bounce back after a massive setback. Programs like the GCRMN and Reef Check must continue to monitor the reefs after this bleaching to assess whether the corals recover or die, whether there is regrowth of damaged corals, or whether new recruits are settling. If the reefs do not recover, this may be a sign that there are other stresses preventing natural recovery, and this information may guide resource managers as to what other pressures must be reduced to speed up the recovery process.

We endorse the efforts of the GCRMN and encourage you to read this book.

Russell Reichelt
Director
Australian Institute of Marine Science
Townsville

Meryl Williams
Director General
International Center for Living Aquatic Resources Management
Manila

Patricio Bernal
Executive Secretary
Intergovernmental Oceanographic Commission

Executive Summary

Clive Wilkinson

How coral reefs respond to stress

Natural resilience of coral reefs to stress

Recent reports from the Global Coral Reef Monitoring Network (GCRMN), Reef Check, and many other projects indicate that coral reefs are under considerable stress and are experiencing considerable damage. Coral reefs have been resilient ecosystems since the Mesozoic (about 200 million years ago), surviving major environmental events such as ice ages, meteor strikes, and large changes in solar activity. Notwithstanding these events, coral reefs have recovered to form the extensive reefs we see today, although recovery may have taken thousands to hundreds-of-thousands of years. For example, during the last ice age (end of the Pleistocene) sea levels fell by over 100 m, killing all existing coral reefs, but corals continued to grow on continental margins and seamounts. When sea levels started to rise 10,000 years ago, corals invaded continental shelves and island slopes and, over the last 6000 years of relatively stable sea level, have been forming new reefs. Coral reefs also have the capacity to regenerate rapidly after catastrophic tropical storms, plagues of the coral-eating crown-of-thorns starfish, and severe bleaching. Recovery often takes 15 to 20 years. However, over the past 50 years, there have been major increases in stresses to coral reefs from direct and indirect human activities. These stresses are threatening the existence of reefs in some areas, and will diminish the value of reefs in other areas. Fortunately the corals on vast areas of remote reefs are unlikely to be severely affected. The same cannot be said about valuable reef fisheries resources.

Natural stresses to coral reefs

The major stresses to reefs are storms and waves, particularly tropical storms and cyclones (called hurricanes in the Atlantic; cyclones in the south Pacific and Indian Oceans; and typhoons in the north Pacific). These cause major intermittent damage to reefs, particularly to those reefs that rarely experience these storms. For example, Guam in the northwest Pacific is hit by one typhoon a year on average, such that the corals are stunted and robust; whereas reefs in the eastern Pacific, such as in French Polynesia and the southern Caribbean, rarely experience such storms, with the result that strong waves from the infrequent storms smash the fragile coral communities.

Freshwater runoff damages reefs in semi-enclosed bays and lagoons of the larger Pacific islands (e.g. Kaneohe Bay in Hawaii) by lowering salinity and depositing large amounts of sediments and nutrients. Reefs are also damaged by volcanic activity (earthquakes, volcanic lava flows, severe uplifting) in the Pacific, for example in Vanautu, the Solomons, Papua New Guinea, the Philippines and Indonesia. Coral bleaching has been particularly notable recently, and particularly damaging from 1997 to 1998. While bleaching is a response by corals to many stresses, the recent apparent increase in incidence and severity may be a foretaste of global climate change (see below).

The major biological stresses on reefs are predation by the crown-of-thorns starfish, and diseases. Starfish plagues can outbreak on reefs in the Pacific and Indian Oceans, and often reappear at 12 to 20 year intervals. In the Caribbean, coral diseases have been particularly devastating in some areas. There is now considerable speculation that the incidence of both these stresses has been exacerbated by human activities.

Human stresses to coral reefs

Increases in human populations and economic activity in the tropics over the past 50 years have resulted in increasing pressures on adjacent reefs. The major damaging factors to reef corals are: pollution from excess sediment and nutrients because of poor land-use practices on high islands, agriculture, industries, urban sewage and over-fishing. The major stress to remote reefs is from over-fishing, particularly the use of destructive methods in the Indo-Pacific over the past 10 to 20 years. In 1997, the first GCRMN/Reef Check global coral reef survey revealed that most reefs show clear evidence of local extinction of species, and obvious damage from blast and poison fishing in the West Pacific. The value of, and demand for, reef fisheries products has increased rapidly, particularly for export to east Asia. The surveys showed that key indicator species, such as giant clams, lobsters, sea cucumbers, pearl shell and trochus, and reef sharks have been removed. Now high-priced fish such as grouper, humphead wrasse, snappers, and parrot fish are being removed from reefs throughout the Indo-Pacific through the use of fine-mesh gill nets and traps, dynamite (usually home-made), and poisons, such as cyanide and bleach. Subsistence fishing is depleting fish stocks in the Caribbean, particularly through the use of fine-mesh traps and nets.

STATUS OF THE WORLD'S REEFS

The first and second global GCRMN/Reef Check surveys showed that most of the world's reef corals are in good to excellent condition, because they are either remote from human populations, or are under good management, such as the Great Barrier Reef. But these surveys also showed that management in most marine parks is failing to stop the loss of

high-value, edible species, and that greater attention is needed to improve management. The ecological balance in many of the world's best reefs has been altered by the removal of high-value organisms.

A recent estimate by the World Resources Institute in Washington suggested that as many as 56% of the world's reefs are threatened. Finally, there are those reefs that have been severely damaged or destroyed. Approximately 10% of the world's reefs fit into this category, being mined for sand and rock, reclaimed for development (particularly for airports), or have been buried under sediment washing into the sea from inappropriate land use.

Fortunately most reefs have a high capacity for recovery, and if pressures are reduced or removed, many damaged reefs will rebound to a healthy status.

Status of Middle East coral reefs

The Red Sea reefs are only affected in a minor way by human disturbances. Consequently the reefs are in near-pristine condition, and few threats loom on the horizon. Reefs on the Arabian Sea coast are heavily influenced by cool upwellings, which limit coral growth and favour the growth of large algae. But these reefs are only marginally affected by human activities, and remain in good condition. The shallow fringing reefs in the Arabian Gulf are impacted by high sediment runoff, and large fluctuations in temperature and salinity, hence they are not well developed. Also they have been severely impacted by coral bleaching in recent years. There is little active coral-reef management in the region, however, there are projects to increase management capacity and conserve some valuable reefs. An imminent threat to these reef systems is oil pollution from increasing tanker traffic.

Status of western Indian Ocean coral reefs

The status of reefs ranges from those in virtually pristine condition, such as the atolls in mid-ocean, to reefs that are heavily impacted by human activities, such as those fringing the coasts of East Africa and Madagascar. Extensive clearing of land and forests in Kenya, Tanzania, and Madagascar has led to excessive sediment runoff, which has damaged many reefs. In addition, there is over-fishing, including the use of explosives, so that these reefs are in medium to poor condition. Some reefs on Mauritius have been impacted by sediment runoff from sugar-cane farming, and by over-fishing, whereas the reefs of the Comoros and Seychelles are mostly in good to very good condition, except immediately adjacent to large population centres. Reef management is not well developed, and fisheries and coastal development are poorly regulated. Rapidly increasing populations and tourism are contributing to reef destruction. Recently there has been significant progress in reef

management in the Seychelles, Mauritius, Kenya, and Tanzania, particularly in establishing marine protected areas for tourism. Efforts at increasing community-level management are proving successful in some areas of Kenya and Tanzania.

Status of south Asian coral reefs

The coral reefs of south Asia vary considerably. In the Maldives, Laccadive/Lakshadweep and Chagos atolls the status of the oceanic reefs is very good, and virtually undisturbed reefs fringe the Andaman and Nicobar Islands. In contrast, the fringing reefs and patch reefs off India and Sri Lanka are predominantly in poor condition, and increased sedimentation, pollution, coral mining, and intensive fishing, including for the aquarium industry, are major problems. Tourism is now the mainstay of the economy in the Maldives, and is increasing in Sri Lanka and the Andaman Islands. Virtually all reefs in South Asia (except Chagos) have suffered major damage from coral bleaching in 1998. Environmental awareness is increasing, and reef management is gradually improving.

Status of southeast Asian coral reefs

Approximately 30% of the coral reefs of the world are in southeast Asia, the global centre of biodiversity for hard corals and many other reef animals and plants. But the populations and economies of the region are growing rapidly, mainly in coastal areas, and the result is non-sustainable use and degradation of many reefs, particularly those close to major populations. Some remote reefs may still be healthy, but fishers are moving throughout the region, taking fish by destructive means, especially cyanide. The demand for healthy reefs for tourism may increase reef conservation because tourism can generate long-term sustainable income if managed carefully. Many reefs have been monitored and show a steady decline in live coral cover over the last 15 years. As a response, more marine protected areas have been gazetted, but less than 10% are well managed. Although awareness of the importance of reefs is increasing, recent economic problems will mean that reef conservation may take a lower priority.

Status of Australian coral reefs

The major stresses to Australian reefs are natural, such as cyclones, coral bleaching, and crown-of-thorns starfish. Human stresses are minimal, except on some reefs close to the land, because population density is low, the economic status is high, and fishing pressure is low. Major research is underway to ensure that fishing is sustainable for target species, for total catch, and for reef health. All Australian reefs are efficiently managed, local support for reef management is strong, and compliance is achieved more by education and involvement than by enforcement.

The bulk of the Great Barrier Reef is in good condition because most of it is remote from land influences, but inner shelf reefs may have suffered impacts resulting from increased sediment and nutrient runoff caused by cattle grazing and sugar-cane farming. However the farming industry is working out of both self-interest and concern for the environment to reduce the impacts of sediment and nutrient runoff. All tourist resorts are now required to treat sewage to avoid any runoff, and to manage the areas of reefs that they use.

Reefs off Western Australia are in good health as they are generally not impacted by land influences, and no impacts have been attributed to petroleum exploration or fishing. There is strong recognition by government that the tourism and resource values of coral reefs are particularly high, which means that reef management receives sufficient attention.

Status of northwest Pacific reefs

Reefs of China, Japan, and Taiwan are normally impacted by typhoons and crown-of-thorns starfish, and recently have been severely damaged by sediment, pollution, and over-fishing, including blast and cyanide fishing. Reefs of the Marianas have likewise deteriorated and both coral and fish populations have reduced. However, the reefs of Palau, the Federated States of Micronesia, and the Marshall Islands are in good health, except those around population centres where there is sediment and nutrient pollution. The traditional low-level fishing activity has increased dramatically in response to enormous demand from Asia and America. Giant clams, sea cucumbers, trochus shells, lobsters, and top quality fish are often severely depleted, even on remote reefs. Reef conservation is inadequate, although management is improving in all countries. However, far greater efforts are required to arrest the continuing trend of reef degradation.

Status of southwest and east Pacific reefs

About 99% of all southwest and east Pacific reefs are remote from urban pollution and sediment degradation, and structurally they remain in good to excellent condition. Reefs near large towns provide benefits in subsistence fishing, recreation, tourism, and shoreline protection, but these reefs are being chronically degraded. There is often significant over-fishing, and giant clams, sea cucumbers, and trochus shells are now rare. Sharks and lobsters have been removed from most remote reefs. This is an increasing trend, and involves cyanide and dynamite fishing for Asian markets. The largest natural threats are from storms and strong wave action, along with crown-of-thorns starfish. Concern is increasing about global climate change, coral bleaching, and stronger El Niño events. Rising sea levels will damage the shores of high islands that are rapidly subsiding, and may destroy low coral islands and jeopardise their island cultures. Management is required to reduce or divert increasing population pressures, and integrate traditional management of reef resources into 'modern' methods.

Status of Central American coral reefs

The Pacific coast reefs of Central America are small, have low diversity, and are being heavily impacted by natural and human pressures. Previous large-scale damage from crown-of-thorns starfish and El Niño bleaching is being compounded by sediment runoff from poor land-use practices. The reefs are remote from external sources of coral larvae, are continually stressed by cold upwellings, and damaged by bio-eroding animals; their potential for natural recovery is very poor. There is little active conservation and very few reefs are protected.

Caribbean reefs off Belize and well offshore to the south have high biodiversity and are in good to excellent condition. Most reefs were heavily damaged by coral bleaching, diseases, and death of the long-spined sea-urchin, but recovery has been good to patchy. Recovery had been poor on reefs being polluted by increased sediment and nutrient runoff resulting from poor land use, and where reefs were over-fished, for example the reefs off southern Panama. The severe coral bleaching of many reefs which started in mid-1998 continues, and there is major mortality. Hurricanes also pose a significant threat to reefs north of 15°N. Many of the marine protected areas exist only on paper, but a major project (Mesoamerican Barrier Reef Initiative) aims to increase monitoring and management of reef resources.

Status of northern Caribbean coral reefs

Most reefs in the northern Caribbean are in fair to relatively good condition, with a few degraded reefs. Some reefs are limited by natural conditions, including hurricanes, and human pressures vary from very high (e.g. off Haiti, and Veracruz in Mexico), to low (e.g. Flower Garden Banks, parts of the Bahamian and Cuban archipelagos). Coral diseases, such as white-band disease, have reduced coral cover on many reefs and the death of the algal-grazing urchin, Diadema antillarum, has resulted in proliferation of fleshy algae, particularly near sources of pollution and in highly fished areas. Stocks of reef fish also vary with socioeconomic conditions and the level of effective management. People are becoming more aware of the ecological and socioeconomic values of reefs, and conservation and sustainable management efforts are increasing.

Status of central Caribbean coral reefs

Awareness of the need for reef conservation is particularly high on Bonaire and the Cayman Islands because reef tourism is a dominant part of the economy. These reefs are essentially healthy with few pressures. However, off the mainland (Colombia and Venezuela) and on Jamaica, reefs have been damaged so that there are fewer fish, more algae, and less coral cover, and current conservation efforts are insufficient to prevent ongoing damage from sediment, nutrient pollution, and over-fishing. Corals have also suffered from bleaching, diseases, and Diadema die-off. Cayman and Bonaire have well-

developed reef management strategies, which are being used as examples for the rest of the Caribbean.

Status of eastern Caribbean coral reefs

The Lesser Antilles include high volcanic islands with very narrow continental shelves, and some low coral islands with wider shelves. There are some excellent coral reefs, which are normally stressed by sediment runoff from heavy rains, and by hurricanes. Recently, coral bleaching, coral diseases, tourism, and fishing pressure have resulted in some degradation in many areas, but there are few long-term studies to determine the status of reefs or the trends in their condition. The number of reefs under active and effective management has increased, and the need for better management is being recognised. Community-based management on St Lucia may prove to be a model for the region.

THE CORAL BLEACHING EVENT OF 1997–1998

There has been unprecedented bleaching of hard and soft corals throughout the coral reefs of the world from mid-1997 to late-1998. Information is coming in daily via the internet and from GCRMN and Reef Check teams. Much of the bleaching coincided with a large El Niño event, followed by a strong La Niña, but bleaching in other areas appears uncorrelated. Four overlapping levels of bleaching are apparent:

- 'catastrophic', with massive mortality (often near 95% of shallow corals) in Bahrain, the Maldives, Sri Lanka, Singapore, and in large areas of Tanzania;
- 'severe' bleaching with around 50–70% mortality, and also coral recovery, in Kenya, Seychelles, Japan, Thailand, Vietnam, and Belize;
- 'moderate and patchy' bleaching on some reefs in large areas, with a mix of coral recovery and around 20–50% mortality, but no effects in other parts, such as in Oman, Madagascar, the inner Great Barrier Reef, parts of Indonesia and the Philippines, Taiwan, Palau, French Polynesia, the Galapagos, the Bahamas, Florida, the Cayman Islands, Bermuda, and Brazil;
- 'insignificant' or no bleaching in large areas of the world's reefs such as the Red Sea, the southern Indian Ocean, the Andaman Sea, most of Indonesia, large parts of the Great Barrier Reef, most of the central Pacific, and parts of the southern and eastern Caribbean.

Bleaching and mortality were most pronounced in shallow water (less than 15 m) and particularly affected staghorn and plate Acropora and other fast growing corals. Many of

the massive, slow-growing species bleached, but many recovered within 1 or 2 months. The consensus is that this is the most severe bleaching event ever observed, although in this case there were also more people looking specifically for bleaching following internet advice of the location of above average sea-surface temperatures. More observations and monitoring are required to determine whether bleached corals will recover (or die), and whether damaged reefs have the potential to 'bounce back'. More importantly, there is a need for continued observations to determine whether this is a rare, severe event, or part of a pattern of increasing disturbance associated with global climate change.

GLOBAL EFFORTS TO CONSERVE CORAL REEFS

The international community responded to alarm calls on the status of coral reefs in the early 1990s with major initiatives. The International Coral Reef Initiative (ICRI) was catalysed by the USA in 1994 and now has the participation of Australia, France, Jamaica, Japan, the Philippines, Sweden, UK, and major agencies like UNEP (United Nations Environment Programme), the Intergovernmental Oceanographic Commission of UNESCO, the World Bank, ICLARM (International Center for Living Aquatic Resources Management), and SPREP (South Pacific Regional Environment Programme). ICRI has consulted over 100 countries to catalogue their concerns, requirements, and ideas, and to document their actions to conserve reef resources and has developed a major strategy that has been endorsed by over 80 countries — the ICRI Call to Action and Framework for Action. This strategy will be reviewed, and progress will be evaluated at the International Tropical Marine Ecosystems Management Symposium in Townsville, November 1998.

One universal call from the international community was for more information and data on the status of reefs. This catalysed the formation of the Global Coral Reef Monitoring Network (GCRMN) under the sponsorship of IOC/UNESCO, UNEP, IUCN (the World Conservation Union), and the World Bank. The GCRMN is assisting about 80 countries to form nodes, built around existing expertise, to provide training in monitoring the reefs and to work with communities to assess reef-use patterns. These two themes bring in expertise from the two host organisations, AIMS (Australian Institute of Marine Science) and ICLARM, with considerable funding from the government of the USA. Monitoring has started and the data gathered are flowing into ReefBase, the global database housed in ICLARM. This book is a product of the GCRMN.

A parallel monitoring programme involving volunteers — Reef Check, joined the GCRMN to broaden global monitoring to include user communities. The first truly global surveys in 1997 and 1998 gathered data using one method for comparison from over 300 sites around the world. This programme, based at the Hong Kong University of Science and Technology, uses basic assessment methods to document exploitation of reef resources throughout the

world. Reef Check has built up a strong following among scientists and recreational divers, and achieved a major goal in raising awareness among the public and governments about the need for coral reef conservation. Participation in Reef Check is the first step towards community-based management and this has now occurred in over 40 countries.

CARICOMP (Caribbean Coastal Marine Productivity Program) is an environmental monitoring programme that includes reefs, which will coordinate monitoring in smaller Caribbean countries and states for the GCRMN. A coral reef mapping project called AGRA (Atlantic and Gulf Reef Assessment) was launched by scientists at the University of Miami in Florida in 1998, to map reef health. Another programme, (AQUANAUT) has been developed by ICLARM to train divemasters to lead reef assessment teams.

The problems facing coral reefs and the people who use and appreciate them are enormous and increasing. But in parallel there is increasing global awareness of the need for action, and many people, agencies and countries, are putting resources to reef assessment and conservation. A new integrated programme combining many of the initiatives above — the International Coral Reef Action Network, working within the Regional Seas network of UNEP — is now seeking funds to enable the move from consulting, meeting, and planning, to action and results to conserve global reef resources.

1. The 1997–1998 mass bleaching event around the world

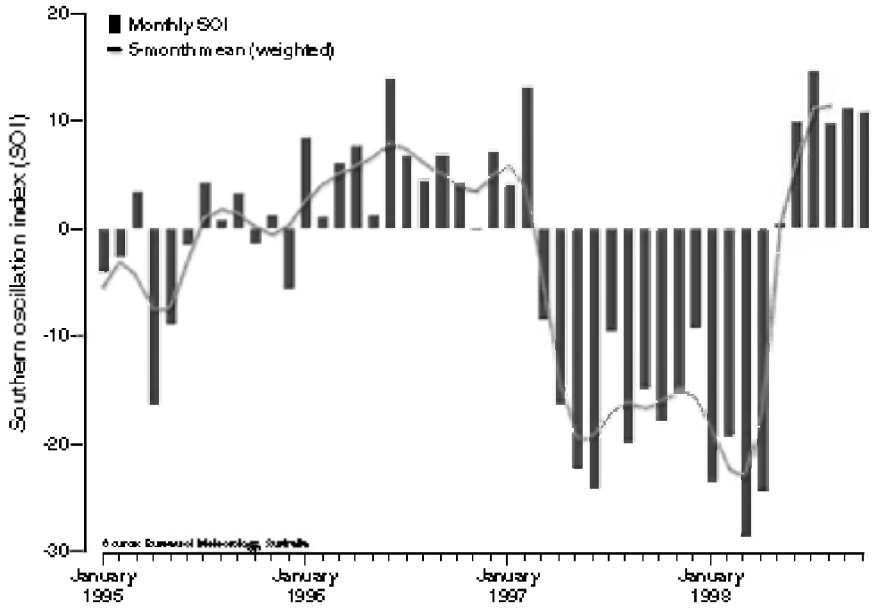
Compiled by Clive Wilkinson

Abstract

There has been significant bleaching of hard and soft corals in widely separate parts of the world from mid-1997 to the last months of 1998. Much of this bleaching coincided with a large El Niño event, immediately switching over to a strong La Niña. Some of the reports by experienced observers are of unprecedented bleaching in places as widespread as (from west to east) the Middle East, East Africa, the Indian Ocean, South, Southeast and East Asia, far West and far East Pacific, the Caribbean, and the Atlantic Ocean.

There was a wide spectrum of reports on bleaching ranging from:

- catastrophic bleaching with massive mortality, often near 95% of shallow (and sometimes deep-water) corals such as in Bahrain, the Maldives, Sri



Coral bleaching followed the climate switch from El Niño in the East Pacific (low SOI values) to La Niña (high SOI) around Australia and Asia.

Lanka, Thailand, Singapore, and parts of Tanzania; through

- severe bleaching over large areas with significant mortality (around 50% to 70%) with recovery of larger, more resistant species (Kenya, Tanzania, the Seychelles, Thailand, Vietnam, Japan and Belize); to
- severe bleaching only in some of the reefs, with a mix of recovery and mortality (around 20% to 50% in places), for example Oman, Madagascar, the Great Barrier Reef, parts of Indonesia and the Philippines, Taiwan, Palau, French Polynesia, the Galapagos, the Bahamas, Cayman Islands, Florida, Bermuda, Brazil; and
- finally, on large areas of the worlds reefs, insignificant or no bleaching was observed.

Bleaching was most pronounced in shallow water (less than 15 m) and particularly affected staghorn and plate Acropora and other fast growing species, with a high proportion of coral death. Slower growing massive species, like Porites, also bleached, but many recovered within 1 or 2 months. Some people commented that bleaching like this had not been seen in 40 years of observations.

While this was occurring, there were large areas of the world where bleaching was not observed. Little or insignificant bleaching was seen in the Red Sea, southern Indian Ocean, Andaman Sea, most of Indonesia, large parts of the Great Barrier Reef, most of the central Pacific and many parts of the southern and eastern Caribbean. In some places with no bleaching, severe bleaching similar to that observed above had occurred in past years, with significant recovery since then.

The consensus is that this is probably the most severe bleaching event ever observed, but there were far more observations and observers this year, and a greater degree of interest in reporting bleaching. Many of the bleaching reports, possibly 80%, are estimates and the reports of bleaching may be exaggerated because bleached corals are particularly dramatic. However, amongst the reports there are actual measurements which often are close to the estimates. Much of this interest has arisen because regular, real-time reports are available on sea-surface temperatures over the internet and on e-mail lists through the National Oceanographic and Atmospheric Administration of the USA. Now the large questions are whether observed bleaching will result in death or recovery of the corals, and whether there is potential for the damaged reefs to bounce back and recover from this event. But the most important question is whether this is just a severe, one-off event, as it now appears, or whether events like this will occur more frequently as the world's atmosphere and waters warm up.

Introduction

There has been unprecedented bleaching in coral reefs throughout the Indian Ocean, Southeast Asia, the Caribbean, and parts of the far eastern and western Pacific Ocean. This bleaching has been in parallel with big swings in the global climate with a severe El Niño event during late-1997 and early-1998, which switched over to a strong La Niña in mid-1998.

The coral bleaching of 1997–1998, is the most geographically widespread ever recorded, and probably the most severe in recorded history. Bleaching means that corals (both hard and soft), as well as giant clams and some other animals like sponges, lose their symbiotic algae (zooxanthellae) and/or the pigments of those algae, such that the coral appears pale to stark white. Some bleaching may be a seasonal event in the Pacific, Indian Ocean, and the Caribbean, and full recovery is the norm. Frequently corals recover from bleaching, but death may result if the stress is extreme or prolonged. Normally fast-growing, branching corals in the Indo-Pacific are more susceptible than slow-growing boulder corals, which if they are bleached, frequently recover in one to two months. In this year's bleaching event, there has been widespread death of the fast growing corals, and also bleaching of the more resistant forms — the boulder and plate-like corals. For example, some 700-year-old Porites corals on inner reefs of the Australian Great Barrier Reef and Vietnam have been extensively bleached, and some have died. Complete recovery of these reefs will be slow.

Mass bleaching can occur when sea-surface temperatures (SST) rise well above the average for summer and this stresses corals. Frequently the warmer temperatures coincide with more solar radiation, particularly during very calm periods. Bleaching also occurs during extreme low tides or heavy freshwater runoff onto reefs. This time, bleaching has been seen both in shallow water down to very deep water, for example 50 m deep.

There are some correlations between the widespread coral bleaching in 1997–1998 and one of the strongest El Niño events of this century, but the patterns are unclear with many exceptions. The correlation exists for the east Pacific, but the bleaching in southeast Asia coincides with a strong La Niña (the complete reverse of El Niño), and the bleaching in the Indian Ocean and parts of the Caribbean do correlate with either El Niño or La Niña.

The 1997–1998 episode of worldwide bleaching is a major cause for concern. Although sea temperatures have returned to normal in many tropical areas, the full extent of bleaching-induced mortality may not be fully apparent for several months yet.

This report was only possible through the cooperation of many, many people throughout the world (whose names are listed after the country reports), and through the power of electronic mail, particularly using a list <coral-list@coral.aoml.noaa.gov> run by the National Oceanographic and Atmospheric Administration of the USA. Reports received varied from detailed accounts with accurate measures of bleaching and mortality, to brief anecdotal reports obtained during a rapid site visit. While it is being published for the International Tropical Marine Ecosystems Management Symposium in Townsville in November 1998, it is also being lodged on the internet and hopefully upgraded as more reports come in. Many of the reports were very detailed; I edited them to reduce the length of this report, so any errors are probably mine, not the authors.

Middle East

The waters of the Arabian/Persian Gulf experience major variations in temperature from lows of around 15°C to highs of mid-30°C. Thus the corals are adapted to wide fluctuations in temperature (as well as salinity). Extensive bleaching was seen in the Gulf in 1996, and now there has been extensive bleaching over the entire Arabian Gulf and parts of the Arabian Sea in 1998. The Gulf of Oman and Arabian Gulf are subject to considerable upwellings, which lower temperatures and stress corals (which in turn favours the growth of macroalgae).

The Red Sea also experiences warm temperatures, but bleaching is an infrequent event and some localised bleaching was seen over several months of mid-1998. There was considerable bleaching in the Red Sea in 1996.

Bahrain

1998 was a very hot year on land, and coral bleaching was first observed in mid-August when water temperatures went from 34°C to 37°C in a week, and stayed that way for a few weeks (up to 39°C in shallow areas). There was 100% bleaching from Hayr Shutaya (32 km north of Bahrain) south to Fasht Al Adhom, and Fasht Al Dibal (all less than 10 m depth). Coral mortality was 90% to 95% a few weeks later, and surviving corals were still bleached in October. Bleaching was estimated at 50% on Abul Thama (about 80 km north of Bahrain). There was major bleaching in summer 1996 when water temperatures were 37.3°C at Fasht Al Dibal, and most corals on Fasht Al Adhom bleached then died. Now many of the corals at Abul Thama that survived 1996 have bleached and died.
(Roger Uwate)

Eritrea

Water temperatures around Massawa and Green Island have been extremely high (40°C) in August and September, resulting in bleaching on deep and shallow reefs. After the

temperatures dropped, most corals recovered to their original state, but some in shallow water have died. No bleaching at all was seen around the islands of Assab.
(Marco Pedulli)

Oman

Extensive bleaching was observed, with temperatures of between 29.5°C and 31.5°C, at eight sites around Mirbat, southern Oman, between 22 May and 26 May 1998. Between 75% and 95% of Stylophora (the most abundant coral genus) bleached, and 50% of large Porites colonies were partially bleached. About 95% of coral were still living despite losing their zooxanthellae. But no bleaching was observed at Sudh, 40 km to the east of Mirbat, where seawater temperatures varied between 25°C and 25.5°C, nor in the Muscat area, Gulf of Oman where water temperatures in early June were 30.5°C. Also no bleaching was observed on the Hallaniyat islands, from February to April 1998, about 75 km northeast of Sudh. Normally, upwelling during the southeast monsoon drops temperatures to 19°C. This was described as a pristine area with coral cover from 10% to 90% growing down to 35 m where macroalgae and corals coexist in waters which vary from very cool to very warm. No recovery of bleached colonies was seen in mid-October when temperatures increased to 25°C after the summer upwelling period.
(Robert Baldwin, Simon Wilson, Peter Collinson)

Saudi Arabia

Widespread coral bleaching was seen on four patch reefs in the Gulf (seawater temperatures 35–36°C) in mid-August, 1998. There was very high mortality (about 95%) in Acropora and other species (especially Platygyra daedalea, a common nearshore coral) that had survived bleaching in 1996. Bleaching was minimal on an offshore island reef with seawater temperature below 34°C. Severe bleaching in 1996 killed high percentages (>90%) of Acropora on nearshore platform and patch reefs, as well as damaging the Porites dominated reefs in the north.
(Yusef Fadlallah, Reynaldo Lindo)

United Arab Emirates (UAE)

Bleaching started in a marine protected area off the UAE in 1996, and this year (1998) the entire reef appears to be dead. This used to be a beautiful coral reef.
(Fareed Krupp)

Yemen (Socotra)

Extensive coral bleaching was seen on the islands of Socotra off the Horn of Africa in May, 1998 with high mortality.
(Catherine Cheung, Lyndon de Vantier)

INDIAN OCEAN

The extent of bleaching in the Indian Ocean during 1998 is unprecedented in both extent and severity. Warm surface waters migrated from south to north during the first six months, with considerable coral reef bleaching occurring in each locality. The warm pool of water was observed in satellite images from the National Oceanic and Atmospheric Administration of USA in January 1998. This bleaching is similar, but more severe than the1987 El Niño in the Indian Ocean, which caused some mortality, but the reefs recovered quite quickly in the Maldives.

Chagos

The atolls apparently escaped bleaching as none has been reported in the past two years. No details are known.

(CHARLES SHEPPARD)

Comores

In late May, bleaching was observed on the two islands: Grande Comore (near the airport); and Galawa (near beach hotels). Bleaching was seen from the air, possibly linked to freshwater runoff.

(JEAN-PASCAL QUOD)

India

The outer-atoll seaward slopes of Kadmat in the Lakshadweep Islands, India had live coral cover of around 80–90% in places. A Reef Check survey showed heavy mortality with only 3% live coral cover and 87% dead branching and table forms at 3 m. At 10 m, live coral cover was 7%, with 43% dead coral cover, and 38% rocky substrate. Bleaching at Kavaratti Island, Lakshadweep islands in May appears similar to what was seen in the Maldives, although perhaps less severe. Not all reefs in Lakshadweep have been so severely affected. Some bleaching, between 10% to 30%, was seen in the Gulf of Kutch on the northerly Gujarat coast in early to mid-May. Reports are coming in of bleaching in the Andaman islands.

(ARJAN RAJASURIYA, JASON RUBENS)

Kenya

Bleaching started north of Lamu (2°S), on 18 March 1998, when temperatures reached 32°C, and continued during April. Bleaching around Mombasa started around the same time and was as low as 50%, but mostly near 100% on almost all reefs seen, where there had been 20–50% coral cover. Bleaching was most extreme in shallow water, but was also 50% or

more at 20 m. Coral mortality ranges between 50% to 90%, with reefs now having 1–10% coral cover, with 10–50% of the remaining live corals still bleached in mid-October.
(David Obura)

Madagascar

There was bleaching of 30% of corals at Belo sur Mer (mid-west coast), with water temperatures of 32–33°C in February and March, and similar bleaching at Antananbe, Toliara, Nosy Bé, Mitsio archipelago, and Mananara-Nord, Masoala peninsula (northeast coast, 15°S). No distinction in species was involved at most sites, but at Mananara, Acropora corals in shallow water were 40–80% bleached with high mortality, and 10–40% of mixed species corals were bleached in deeper water. Another report from Toliara/Tulear for September indicated that there was no bleaching nor crown-of-thorns damage and that the reefs were in a good state of health.
(Jean Maharavo, David Obura, Charlie Veron)

Maldives

There has been heavy damage to coral reefs in the central tourist region of the Maldives. Relatively severe, rapid bleaching occurred between late April to May, 1998, and now there are signs of partial recovery. Around 80% of corals are wholly or partially bleached on the back reef, with around 45% at 10 m on the reef slope, and 30–40% at 20–30 m. Bleaching was also seen at 50 m. These observations on North Male Atoll have been effectively confirmed by sea-plane operators who observed similar levels throughout the Maldives. Other reports from North Male and the Ari Atoll were of 95% of mostly Acropora communities dead, including soft corals and anemones. Many massive corals are still under stress and partially bleached. Prior to this, coral cover was around 30–50% in shallow water (mostly Acropora), decreasing with depth. Bleaching appears to have killed almost all shallow corals, but effects are less at greater depths, although still severe.

By late May, recovery began for Porites species on South Male and Vaavu Atolls, and colour was near normal by September, but Acropora species suffered major mortality, sometimes up to 100%. On South Male Atoll, temperatures were high, being over 30°C at 30 m from April to June 1998. Here 100% of some Sinularia soft corals bleached (but not Sarcophyton spp.); corals (Acropora, Fungia and Porites were 60–80% bleached; and even giant clams (Tridacna) were partially bleached. Many anemones have since regained their colour. A similar result was seen in the 1970s, with large areas of reefs dead from unknown causes, but recovery was rapid.
(Jason Rubens, William Allison, Norbert Schmidt, Reto Wyss, Zdenka Vapenik)

Mauritius

There was minor bleaching in Mauritius this year, with some small, localised areas of moderate bleaching. Surveys showed from 1% to 15% bleaching in many locations, and up to 50% corals showed a minor loss of colour. Temperatures were about 3°C above the normal of 27°C. On Iles aux Benities, there was moderate bleaching (about 50% in the lagoon).

(Loic Charpy, Ruby Moothien Pillay)

Mayotte

Corals began to bleach at Mayotte (Comoro Archipelago) in mid April on the southern end exposed to the trade winds, and also in the lagoon, which receives cooler water from the north. Very high mortality was seen (maybe 80% of Acropora) on the outer slope, with other main genera affected being Galaxea, Lobophyllia, and Goniopora. Soft corals were also bleached, but Porites was not affected. 'Many bright corals' were seen on the nearby small coral islands of Europa and Juan de Nova.

(Jean-Pascal Quod, Bernard Thomassin)

Réunion

During the last two weeks of March, there was significant bleaching (approximately 30% to 50%) on the reef flats and reef slopes of Réunion, with Acropora, Galaxea, and Pocillopora the genera most affected. Water temperatures were high (but not recorded) and there was very heavy rainfall for most of February. No recovery was seen several months later, with corals now covered with turf algae.

(Michel Pichon, Jean-Pascal Quod)

Seychelles

There was extensive bleaching down to 23 m in the south on Aldabra and Providence Group (9°S; 46–51°E), and Alphonse Group (7°S; 53°E) during March-May 1998. Temperatures ranged from 29°C to 32°C, and 34°C in lagoons. Bleaching and mortality affected Acropora, Pocillopora, and Millepora, with 40–50% bleached and an additional 20–55% recently dead, with significant algal growth. Soft corals (85–95% mortality), anemones, and giant clams also bleached. Corals at 14 sites in the Seychelles Marine Park system that were filmed showed that an average of about 75% died recently (ranging from 50% to 95%). The dead corals were covered with filamentous algae, which were expanding to cover areas of dying corals. Other reports were of moderate bleaching, which was not exceptional.

(Clare Bradshaw, Loic Charpy, Tom Goreau, Kristian Teleki, Mark Spalding, Tom Spencer)

Sri Lanka

Bleaching started about 10 April 1998 in the southwest at the Hikkaduwa Marine Sanctuary with over 75% bleaching in the beginning. Almost all coral species between 1 m and 8 m, except Montipora species, were affected when water temperatures went from the normal 29°C to 30°C to about 35.5°C in mid April and remained above 32°C until late May. Bleaching increased to more than 80% on the reef flat by late April, and on deeper offshore reefs off Colombo. All species appear to have been affected, but soft corals appear to have resisted the bleaching better. Bleaching was noticeable down to 42 m on the southeast coast near Battilacoa in mid-May. No bleaching was observed 100 km further up on the northeast coast of near Trincolamalee in early May.

Corals remained bleached up to early June 1998, with most branching and tabulate Acropora and Pocillopora colonies starting to die off and be covered by algae. Some recovery (regaining normal colour) of about 10% of bleached corals was observed in mid July. Bleaching like this has never been seen in Sri Lanka before; any bleached corals in the past recovered within 3 to 4 weeks.

(Arjan Rajasuriya and Jason Rubens)

Timor Sea Reefs (Scott, Seringapatam, Cartier, Hibernia — Australia)

The remote atoll reef of Scott (14°S, 121°E) had extensive bleaching in May 1998. There was between 70% and 100% bleaching and mortality of corals between 1 m and 9 m, and 40% at 30 m depth. Sheltered shallow sites had up to 75% coral cover, which is now down to 15%, with more corals still dying three months after bleaching started. Some very large corals suffered several bleaching events and are now covered with patches of algae. Soft corals (Sarcophyton and Lobophyton) bleached, and some are disintegrating. Other remote reefs, Cartier and Seringapatam, were affected to a lesser extent. Corals on Hibernia were only slightly bleached.

(Clay Bryce, Luke Smith)

Tanzania

Corals bleached in mid-May 1998 along the whole coastline of Tanzania, from Mnazi Bay (10°S — 15% to 25% of corals bleached) to Zanzibar (6°S — bleaching between 25% and 50%) and Tanga (5°S — about 25% of corals bleached). Acropora species bleached most with 80–95% in Chumbe, whereas about 40–70% of Acropora in other areas bleached. With Porites, some species bleached whereas others were unaffected. Survival after bleaching was about 50% in Mnazi Bay, and 60–80% in Bawe and Chumbe. Survival was very low (less than 40%) in Changuu and Chapwani. Water temperatures were 30.5°C, about 2°C above normal. Bleaching also coincided with much higher rainfalls than other years, and also when spring tidal ranges were about 4.5 m. By the end of October, 80–100% of corals had died in Mafia

Marine Park, which probably was the best coral reef in the country with almost 100% mixed coral community cover over vast areas. On Tutia Reef in the south, there is less than 5% coral still alive, with heavy mortality of Acropora, Porites, and Echinopora. In Chole Bay in the north, 100% of the Acropora were dead, and in the 'coral gardens' of Kinasi Pass, 80–90% of Acropora have died.
(Olof Linden, Chris Muhando, J.L. Solandt)

Southeast and east Asia

Coral bleaching was first observed in Indonesia in January and February as warm waters flowed through the Java Sea eastwards towards Lombok where bleaching was seen in March. During April and May, a warm pool of water developed during the northern summer around Cambodia, Thailand and parts of Sabah, Malaysia. Warm water bathed the Philippines, Vietnam, Taiwan, and Japan in June and July, and also spread southwards towards Singapore and the Riau islands off Sumatra in June and July, before cooling in late July. Warm waters continued around Japan until August when the first typhoon in September cooled the waters.

Cambodia

Corals around Sihanoukville, Cambodia were moderately to severely bleached in mid-May. The water was warm (no thermometers available) and very turbid. The predominant corals are massives (poritids, faviids and mussiids), with few Acropora and Pocillopora species, but most species bleached, with approximately 80% in some places.
(Vicki Nelson)

Indonesia

Bleaching was initiated by a warm current from the South China Sea that flowed through the Java Sea from the Riau Islands as far as Lombok. There was no bleaching to the north in Spermonde Archipelago, southwest Sulawesi (near Ujung Pandang), and Manado, Bunaken, nor around Bangka, north Sulawesi where coral cover varied between 25% and 75%, depending on location and predominant wind direction.

Coral bleaching of approximately 75–100% of the 25% coral cover was seen around Bali Barat National Park (northwest Bali), and at Tulamben (eastern Bali), with many soft corals seen disintegrating. There was less bleaching at Nusa Penida and Nusa Lembongan. Many anemones down to 36 m at Telumban, Bali, were bleached, but others at 44 m were normal. Bleaching in Pulau Seribu off Jakarta, and Karimunjawa Marine National Park (north of Java) started in January and February, continued through May, and by August corals had either recovered or died.

Bleaching ranged from zero to 46% at 3 m (mainly Acropora and Galaxea), and 1% to 25% at 10 m (Pachyseries, Hydnopora and Galaxea), with 50–60% mortality of bleached corals. On the Gili Islands (Air, Meno, Trawangan), facing the Lombok Strait, almost 90% of hard corals bleached (especially Acropora) in March 1998, down to 20 m. In August, there was high mortality, but some massive corals, especially Porites, were recovering.

There was significant coral bleaching, up to 60–70% at some depths, in East Kalimantan (Borneo) during January, however, water temperatures were much **colder** than normal (approximately 23°C) with extensive plankton blooms.
(Irdez Azhar, Imam Bachtiar, Clay Bryce, Alastair Harborne, Taufik Hizbul Haq, Bert Hoeksema, Otty Lalamangkit, Gayatri Lilley, Ghislaine Llewellyn, Suharsono, Yempita)

Japan

Coral bleaching started on Okinawa Island (26°N) in mid-July 1998, when temperatures increased from 25–28°C in June to 28–31.5°C in July. Bleaching increased in August (31°C), but was less extensive on offshore islands (30°C), affecting shallow-water corals (Acropora, Pocillopora, Merulina, Montipora, and Porites). In September, bleaching continued with all corals and spread north to the Japanese mainland, 33°N, and down to more than 20 m on Okinawa. By mid-October most bleached Acropora were dead and covered with algae on Okinawa, however, many Acropora colonies in shallow moats of Okinawa and on offshore islands had survived. Many faviids and Porites regained colour by mid-October with temperatures around 28°C.

Bleaching was conspicuous on Ishigaki Island (24°N; 50–70% bleached) and Amakusa, Kyushu (32°N) when water temperatures went over 30°C in July and August. It was unusual that water temperatures remained high until the first typhoon in September. Most species were extensively bleached, except for minor bleaching in the blue coral Heliopora. Earlier, a few mushroom corals (Fungia) bleached with water temperatures of 28–29°C, which is apparently a regular, annual occurrence. No bleaching was seen down to 30 m in September off the southwest of Shikoku Island (33°N), where there is 75% coral cover of plate Acropora down to 10 m. Previous bleaching was in 1980 and 1983.
(Charles Delbeek, Hajime Kayanne, Tadashi Kimura, Keven Reed, Rob van Woesik)

Malaysia (Sabah)

Coral bleaching has been highly localised and not very significant in Sabah. In mid-May, there was bleaching of 30–40% of all live coral cover in 1–2 m at Pulau Gaya, Sabah (near Kota Kinabalu) with water temperatures of 32°C. In Pulau Sakar up to 30% of all species bleached with 10% dead down to 20 m. Acropora colonies were about 90% bleached and also some

giant clams with about 20% showing bleaching. Less than 5% of corals were bleached in Pulau Baik down to 15 m, especially large polyp species (Symphyllia, Lobophyllia and Lithophyllon). There was minor to insignificant bleaching on Mamutik island (Tunku Abdul Rahman Park), Turtle Islands Park, and off Semporna, Sabah during surveys in July and August. Intensive surveys of Darvel Bay (Lahad Datu) east Sabah (4°N to 5°N, 118°E) in September showed no significant bleaching at 20 reef sites (Pulau Sakar, Pulau Maganting, Pulau Bohayan, Pulau Tabawan, Pulau Baik, Pulau Laila, Bakapit, Bagahak, and Shoal Point).
(Don Baker, Ranjith de Silva, Ridzwan Abdul Rahman)

Philippines

Massive bleaching started in mid-July, and may be still ongoing in western regions where reports are coming in from Bolinao (northwest Luzon), to Puerto Galera and southern Negros Island, central Philippines (Dumaguete, Campomanes Bay, Danjugan Island, El Nido (Bacuit Bay) and Coron Island (Palawan), and Pag-asa Island (Spratleys). Temperatures of 33–34°C degrees were reported, and bleaching went as deep as 28 m (temperatures of 30–31°C) and completely affected soft corals and some anemones. Bleached hard corals were primarily the plating, branching, and foliose forms, with up to 75% of the community bleached in some areas. Massive corals were also affected; faviids were bleached, but large Porites appeared to resist bleaching below 5 m, but not on shallow reef flats of Bolinao and Negros. Black-band disease was observed on a few bleached colonies. Mortality, however, of bleached corals appears to be low. On the well-known Apo Island, some large colonies of Galaxea fasicularlis showed some patchy bleaching. Massive bleaching was also reported in Danao Bay, near Baliangao, northwest Mindanao in October 1998, with bleaching mostly affecting branching corals, and significant rotting of soft corals, but fire coral (Millepora) not being affected.
(Jade Fraser, Fiona Gell, Gillian Goby, Rex Montebon, Laurie Raymundo, David Medio)

Singapore

There was mass bleaching in June and July 1998 probably due to elevated seawater temperatures (33°C when they are normally 28–30°C). The bleaching affected all species of hard corals and extended throughout the entire depth of coral growth. Soft coral mortality was high. When temperatures dropped in July, some corals started to show recovery. This is the first time bleaching has been seen on this scale.
(Loke-Ming Chou, Jeffrey Low)

Taiwan

Coral bleaching was first observed in June, around Penghu Islands (Pascadores Is) during Reef Check 1998. About 30–40% of corals were bleached in 1–5 m, some corals were dead with water temperature around 30°C. In August, extensive coral bleaching was

observed around Posunotao, an offshore island in southeast Taiwan. Over 80% of corals bleached down to 20 m, with water temperatures of 31°C at 20 m and 34°C at 1 m. Posunotao is in the Kuroshio Current, and other regions down current (Kenting Reef and HisaoliuChio) bleached afterwards.
(Allen Chen)

Thailand

Warm water temperatures in April 1998 caused widespread coral bleaching in the Gulf of Thailand from Narathivat province (south) and Trat province (far east), up to Chonburi province (the inner part of the Gulf). But there was no bleaching on the other side in the Andaman Sea. Water temperatures in the Gulf increased from the normal of 28–29°C to above 32°C, such that on Ko Samui it was 35°C. It was first noticed in the tourist centres of Chumpon and Surat Thani. Then bleaching spread north to reefs in the inner part of the Gulf (Koh Samet, off Samaesan) and off Pattaya. In some places, bleaching has affected 100% of Acropora, 80% of Pocillopora damicornis, and about 60–70% of massive Porites, especially in shallow water. Around Chumporn (Ko Kai, Ko Samet and Ko Tao — 10°50'N), 30–50% of corals bleached. Around Sichang Island (inner part of the Gulf) and Mun Islands (Rayong), the impact was 50–60% of corals bleached, with mortality of about half. This is the first report of widespread bleaching in the Gulf of Thailand.
(Tenshi Ayuki, Vipoosit Manthachitra, Suraphol Sudara).

Vietnam

Extensive coral bleaching began in mid-July 1998 in the areas off of Nha Trang (south-central Vietnam), with moderate levels of mortality in shallow water, especially Acropora species. Major bleaching was reported further south in Con Dao National Park (200 km south of Ho Chi Minh City Saigon, and 80 km off the Mekong Delta) with 70% of corals affected at most reefs down to 15 m. These were particularly impressive coral reefs, which had been damaged by Typhoon Linda, November 1997. At most sites, 90% of the dominant table Acropora and many other corals were dead by mid-September, with total losses of about 70–80% of the shallow water coral cover (1–2 m). Bleaching was equally bad in deeper water with 90% mortality of the dominant massive Porites and many other large colonies, for example Lobophyllia. Coral cover loss in deeper water was 60–70%, and hundreds of 2–3 m diameter, massive Porites were killed, including 9 m diameter colonies which were several hundred years old. No bleaching was seen at Hon Mun Island (off Nha Trang) where there is frequent cold upwelling, nor was bleaching seen at Halong Bay (far north off Vietnam).
(Gregor Hodgson, Vo Si Tuan, Sue Wells)

Pacific Ocean (west)

Throughout the bulk of the Pacific, water temperatures were close to normal during 1997 and 1998 however, up against the Australian mainland, warmer temperatures were recorded in January and February, 1998. The majority of the bleaching on the Great Barrier Reef peaked during the last two weeks of February. This did not coincide with El Niño, which normally means warmer temperatures in the east Pacific, not the west. The similarity of 1988 and 1998 bleaching, especially in the eastern hemisphere, makes a case for a possible indirect relationship to El Niño. Later in the year in the northern summer, warm water appeared in the far northwest Pacific, around Japan and Philippines in July, around Taiwan in August, and Palau in September. Typhoons late in the season (September to October) resulted in reductions in temperatures as the high winds and waves mixed warm surface waters with cooler waters from the deep.

Australia

Sea-surface temperatures warmed considerably off eastern Australia during early 1998. Aerial surveys of 654 reefs show that extensive bleaching occurred along the entire length of the Great Barrier Reef (GBR), from Elford Reef (17°S), to Heron Island (23°S). The intensity of bleaching was much greater on inshore reefs than mid-shelf or outer-shelf reefs. Overall 87% of inshore reefs showed at least some bleaching, compared to 28% of offshore reefs. Heavy bleaching was seen on 55% of inshore reefs (with greater that 30% coral cover), compared to 5% of offshore reefs. However, ground truth surveys suggest that these figures are conservative.

Over 100 coral species bleached, including bleaching and partial death of large Porites colonies that were centuries old. This bleaching appeared to be a combined effect of raised temperatures, exacerbated in the central GBR by massive flows of rainwater in January. Soft corals were extensively bleached on these inner reefs with almost all species affected. In the upper 5 m, soft corals are 100% bleached and about 20% bleached at 8–12 m depth. Mortality was high, even in the normally resistant Sinularia. On Orpheus Island, between 84% and 87% of corals bleached, but five weeks later, mortality was between 2.5% and 17%, with the Acropora species being most affected. Pocillopora species were hardly affected. However, 10 km away on Pandora reef, there was virtually 100% mortality of corals down to 6 m depth, but bleaching followed both a temperature rise and extensive fresh water flows over the reef.

In March, bleaching also extended to southern Queensland (Gneering Shoals; 26°S) and northern New South Wales (28°30'S) on rocky reefs with populations of corals up to 50%

coral cover. Water temperatures were around 28°C (maybe as high as 30°C), whereas they are normally in the mid-twenties Celsius. Pocillopora damicornis and Stylophora pistillata were most affected with 60–70% of these species bleached to 15 m depth. In the central GBR, inshore average daily sea temperatures near Townsville exceeded 31.5°C on the reef slope (the likely local bleaching threshold) at 6 m on 12 days and reached a maximum of 32.7°C. No bleaching was observed on the Flinders Reefs (27°S), between these two sites.
(Andrew Baird, Simon Banks, Ray Berkelmans, Daniel Bucher, Lyndon Devantier, Katharina Fabricius)

Fiji

No bleaching was seen during the past year over about 180 km on the south side of the Great and North Astrolabe Reefs (18°S), which have extensive coral cover.
(Joan Koven)

Federated States of Micronesia

About 20% of corals bleached down to 20 m on the northwest and northeast side of Yap, at the beginning of September 1998. Many genera were observed to bleach including: Acropora, Goniastrea, Platygyra, Diploastrea, Mycedium, Goniopora, Porites (massive), Physogyra, Psammocora, Montipora, Pocillopora, Turbinaria, Hydnophora, Astreopora, Echinopora, Stylophora, Favia, Leptoria, Seriatopora, Pavona, and Fungia. Soft corals (Sarcophyton, Lobophyton), anemones (Heteractis), and Heliopora also bleached. Water temperatures were 30–31°C. No bleaching was seen in the lagoon in Chuuk.
(Sandra Romano)

French Polynesia

During a bleaching event on Moorea in 1991, 20% of corals died on the outer slopes, and during another in 1994 bleaching was less severe and more dispersed. Monitoring on another 14 islands has been added to Moorea as a contribution to the GCRMN. Bleaching in early 1998 was variable among atolls and in locations on atolls. Strong bleaching was seen in some areas like Takapoto, where 20% coral cover in 1994 was reduced to 12% after 1998 bleaching. There was also severe bleaching on Rangiroa and Manihi with significant mortality. On Moorea and Bora Bora, coral cover remains at 30% to 50% (normal for French Polynesian outer slopes at 15 m) with minimal bleaching, if any. Non-bleaching mortality was seen on Tikehau Atoll, with a drop in coral cover from 40% in 1994 to 4% in 1998 because of strong cyclonic waves.
(Yannick Chancerelle, Bernard Salvat)

Hawaii

No bleaching was seen in Hawaii and this has been the coldest summer measured (average close to 26°C).

(CINDY HUNTER)

Johnston Atoll

No bleaching was seen, but there was evidence of recovery from a bleaching event a few years earlier. These reefs have nearly 100% live coral cover in suitable areas. No elevated water temperatures were observed by satellite.

(LES KAUFMAN)

Palau

Major coral bleaching occurred in Palau in September, 1998 with water temperatures from 30–32°C. About 75% of corals shallower than 15 m bleached, and in Arakabasan and one of the rock islands ('Cemetary') there was 20–70% bleaching and high mortality. The eventual impact is not known, but the area looks awful. About 70–80% of the corals were bleached down to 30 m off of Peleliu, the Blue Corner, the Big Drop-off (all in the south), as well as Iwayama Bay in the Rock Islands near Koror. Everything that could bleach was bleaching. The hard corals were not yet dead for the most part, but many of the soft corals were dead. This was in mid-September, and there was minimal bleaching at the 'Blue Hole'.

(PAT COLIN, ERIC GUINTHER, SANDRA ROMANO)

Papua New Guinea

Water temperatures below 10 m around Kimbe Bay (New Britain) in August 1998 were 31–31.5°C, and on the surface they were 32–33°C. High mortality of corals was observed with 75% of Acropora affected, and bleaching in many other genera including Porites, Platygyra and Montipora. Some others were partially bleached, and effects were observed down to 50 m. On the southwest side of Kimbe Bay, water was 29.5–30°C, and there was only 10% bleaching of Acropora and only isolated cases of bleaching on other species.

In March 1998 large areas of reefs south of Normanby Island through to Cape Vogel, and Tufi (far southeast PNG) showed coral bleaching from mid-February. Bleaching extended down to 20 m, but was most extensive in shallow water (almost 100% in some areas, including soft corals and anemones). Water temperatures were 29–30°C from December to February, which is not exceptional for Milne Bay. Reefs to the north of Normanby and Fergusson Islands were apparently not affected by any bleaching.

(JAMES CERVINO, JOHN REWALD)

Samoa (Western)

Between 60% to 70% of all Acropora on the reef top bleached within 5–6 days just before the end of February 1998, at Palolo Deep, National Marine Park near Apia. Corals in deeper water appeared healthy. Some bleaching in Samoa was linked to extreme low tides and exposure to air. (Mike King)

Pacific Ocean (east)

Bleaching was first noticed in the Pacific when the 1997 El Niño event resulted in warm water pooling up in the mid to eastern tropical Pacific along the coastline of Central America. Water temperatures of 27-28°C were recorded from June to October 1997 off Panama and coasts further north, which are 8°C warmer than normal. As this pool of warm water expanded, it then affected the Galapagos islands (on the Equator) in December to February, when surface waters were up to 3°C warmer than normal. Bleaching of the corals started at the extreme temperatures around 30°C.

Colombia (Pacific Coast)

The first signs of bleaching were in late-May 1997 with small white patches on Pocillopora sp. when water temperatures were 29°C. More bleaching was observed in July and August 1997 with increased signs of bleaching at similar temperatures. In September 1997, up to 30% of some Pocillopora was bleached, whereas similar corals nearby appeared normal. (Fernando Zapata)

Galapagos

The first bleaching reports were in mid-December 1997, when water temperatures of 28°C were recorded from satellites. Water was 2°C warmer in February and bleaching continued. Nearly all corals on the Galapagos were bleached to some extent by March 1998. The most strongly affected were Porites and Pavona. The genera Psammocora, Diaseris and Cycloseris were bleached on top, but many still had pigment around the bases. Corals bleached down to 30 m, but bleaching was more extensive shallower than 10–15 m depth. Pocillopora, which was most impacted during the big El Niño of 1982–1983, seems to be largely resisting this time. (Andrew Baker, Joshua Feingold, Jerry Wellington, Al Strong)

Mexico (Pacific Coast)

Bleaching was first noticed in July 1997 from the Gulf of California (25°N) to Jalisco (19°N), and in the remote Revillagigedo Islands (18°N). Bleaching peaked August–September 1997 involving about 25% of total coral cover (water temperatures were 31–34°C). The most extensive bleaching occurred at Nayarit (20°N), where about 60% of corals mostly

shallower than 4 m were bleached. Bleaching was 10–15% in the Revillagigedos, with some mortality, but had finished in October. The only significant recovery in the Gulf is from new Pocillopora recruits settling on the old skeletons. This the first time that bleaching has been reported on the Pacific coast.

Very minor bleaching was seen at Oaxaca (16°N) in 1997 with water temperatures at 31°C; all colonies recovered. A sudden drop in surface water temperatures in mid-September 1998 caused extensive bleaching and this is being followed up. No bleaching or death was observed on Clipperton Atoll in November 1997.
(Gerardo Leyte-Morales, Hector Reyes)

Panama (Pacific Coast)

There was significant coral bleaching on 17 September 1997 at Uva Island, Gulf of Chiriqui. All coral species were affected down to 20 m. Millepora intricata, the most common species remaining after the 1982–1983 El Niño, bleached and died. Other species were still alive but bleached.

Almost all coral species in the Gulf of Chiriqui region started bleaching in mid-April 1998 with 50% to almost 90% of corals at least partially bleached. This follows the bleaching above, but is much less intense than in 1983. Bleaching occurred when water temperatures were 29–31°C, more than 1.5°C above normal. Corals from the nearby Gulf of Panama showed much less bleaching.
(Andrew Baker, Mark Eakin, Peter Glynn and Juan Maté)

Caribbean Sea

The most notable prior bleaching events were in 1983 and 1995. In 1983, there was large-scale mortality of corals along the Caribbean coasts of Panama and Costa Rica. Many of the affected reefs have not recovered their previous levels of coral cover, with the predominant shallow water corals of Agaricia and Acropora now being much reduced. Bleaching this time appears to be spread over a very long time span and in widely separate locations.

Bahamas

Corals of the central Bahamas showed extensive bleaching in August 1998, with over 60% of all head corals bleached to 20 m around New Providence Island. Extensive bleaching of around 80% was seen between 15–20 m depth. Montastrea cavernosa was not bleached, and Acropora palmata bleached on the upper sides only of branches in shallow water. Near complete bleaching of all the corals and some gorgonians was seen at Little Inagua,

Sweetings Cay, Chubb Cay, Little San Salvador, San Salvador, and Egg Is. Samana Cay was much less affected. Hurricane Bonnie then caused water temperatures to drop by 2°C. There was also extensive bleaching at Walker's Cay in the northern Bahamas, and many types of coral were affected.
(Benjamin Mcpherson, Eleanor Phillips, Bill Precht)

Belize

Large areas of the Belize coral reef ecosystem experienced massive coral bleaching in early September 1998 and this continued in October. There was severe bleaching to at least 8 m on the fore-reef, and on the reef top and back-reef of the following: the main barrier reef at Ranguana Pass; patch reefs at Bird, Crawl, Laughing Bird, Scipio, South Water, and Cocoplum Cayes; pinnacle reefs between Ranguana Pass and Lighthouse Caye off Placencia; offshore reefs of Glover's Reef Atoll and Ambergris Caye; and shallow banks off Rum Point. On Glover's Reef, bleaching was measured at 76% on the western fore-reef (near Baking Swash) at 12–15 m, and estimated at 70–80% on the shallow patch reefs in the lagoon and on the eastern fore-reef down to at least 25 m. Bleaching was between 25% to 30% on barrier reef sites (Gallows Reef, near Goffs and Alligator Cayes, and near Calabash Caye, Turneffe Atoll) to depths of 14–18 m. The bleaching is correlated with exceptionally warm water, and calm weather. Water temperatures have been consistently between 30°C and 32°C, and on the surface near some of the cayes, it was between 36°C and 38°C. Almost all hard corals and the zooanthid Palythoa exhibited some bleaching. Total to high bleaching was prevalent in Millepora, Agaricia, and Porites. High to moderate bleaching affected Montastrea, Siderastrea, and Diploria. Moderate to low bleaching occurred in Dendrogyra and Acropora, although A. palmata was only moderately bleached on the main barrier reef, but some totally bleached colonies were seen in lagoon patch reefs. Low to moderate bleaching was seen on the central barrier reef, and Turneffe Atoll. Mortality of bleached corals throughout Belize appears to be about 20–25%. Similar bleaching was seen in 1995, but not to this extent.
(Tom Bright, Melanie McField)

Bonaire (Dutch Antilles)

Less than 15% of corals bleached in August and September 1998, with partial bleaching in Montastrea annularis between 10 m and 20 m and in Agaricia below 20 m. Only a few, small corals in shallow water appear to have bleached. Later in September, nearly 100% of all Agaricia bleached from 8 m to 30 m, but bleaching was not observed in other species with water temperatures of 30°C at the surface to 30 m and 29.5°C below that.
(Kalli De Meyer, John Ware)

Cayman Islands

Unprecedented bleaching occurred during late September 1998 on Little Cayman and Grand Cayman, with all species affected and possibly 90% of all corals heavily bleached. There was some bleaching of Acropora palmata and Montastrea annularis at 1–5 m depth, and widespread bleaching and some mortality to the abundant Millepora. Even previously resilient Montastrea cavernosa partly bleached. Between 50% and 60% of large colonies of Montastraea faveolata bleached around Grand Cayman, but with less bleaching on the West Wall.
(PHIL BUSH, JASON DESALVO)

Colombia

Only a few bleached corals were seen at Isla San Andres in September 1998. By early October, there was minor bleaching (5–10%) at Islas del Rosario affecting Millepora, Acropora palmata, Siderastrea, Agaricia, Porites, Montastraea and some gorgonians. No significant bleaching was seen in the Santa Marta area in October.
(JEREMY WOODLEY)

Cuba

No bleaching has been reported on southern Cuba, however there is a report of extensive bleaching at Herradura and Varadero (west and east of Havana respectively) in late August, 1998 for two weeks. Millepora was extensively bleached, as well as some Montastrea annularis (colony tops), Porites and zoanthids (nearly 30% of all colonies). Near Santiago, there was bleaching down to 35 m depth, probably of Agaricia. Bleaching was seen in places where it was rare or never seen before.
(PEDRO ALCOLADO, JUDY LANG, ALAN LOGAN, PETER SALE)

Dominican Republic

No mass bleaching was seen by the dive operators who dive all over the country.
(PAUL MEDLEY)

Florida (USA)

Scattered bleaching was observed in inshore waters of the Florida Keys in early August 1997, with some colonies partially bleached and others extremely mottled or blotched. Small colonies were entirely bleached. Extensive bleaching of large coral heads in the Gulf of Mexico area of the Keys (Boca Grande Channel, between Boca Grande Key and the Marquesas Keys) was also reported. There was significant recovery.

In July and August 1998 there was bleaching at Coffins Patch Light in the Florida Keys, with water temperatures of 30–31°C. Minimal bleaching was observed in Millepora colonies,

but there was none on nearby Coffins Patch Special Protected Area (SPA). In late August 1998 extensive bleaching was seen in Western Sambo Ecological Reserve, Florida Keys. Surface water temperatures were 30–32°C, but only 26°C at 10 m. Bleaching was seen in up to 90% of Acropora palmata, with some mortality, 50–80% of Montastrea annularis and A. cervicornis, and 40–60% of other corals. There was moderate bleaching between 10 m and 30 m in Dry Tortugas National Park, and on the Tortugas Banks in early September 1998. Approximately 15% to 25% of colonies were affected with water temperatures around 30°C. There was also evidence of bleaching at Ft. Jefferson. In September there was significant recovery of corals on an inshore patch reef, known as the Rocks, that had been severely bleached in June, and very little mortality was evident. Hurricane Georges dropped temperatures to 28°C and did little physical damage. However corals in many areas still appeared bleached and brain corals did not show the recovery seen in other species.
(Billy Causey, George Garrett, Ben Haskell, Walt Jaap, Alina Szmant)

Guadeloupe

Severe bleaching is reported.
(Claude Bouchon)

Haiti

An extensive coral bleaching event was reported after Hurricane Georges in September.
(Jean Wiener)

Honduras

Up to 50% of live coral cover showed bleaching from 10 m to 25 m around Roatan from mid-September 1998, with most species affected, especially Agaricia, Montastrea, and some Diploria. Small amounts of Acropora and Millepora were only slightly affected. No bleaching was seen around the Bay Islands.
(Marea Hatziolos)

Jamaica

Temperatures rose to 29–30°C in late September at Discovery Bay below 30 m. By early October, 70–75% of all Montastrea colonies were bleached, and were still mostly white by mid-October (temperature maximum of 31.5°C). In Portland Bight (south coast) in early October, divers were astonished to see both bleached corals and white gorgonian sea-whips.
(Jeremy Woodley, Ian Sandeman)

Mexico

Bleaching started in late August in Quintana Roo with temperatures around 30°C, and near 33°C in the lagoon. They were still high in September (29.5–30.5°C). By mid-October, 15 coral species showed some bleaching, but it was variable, with Agaricia and Millepora more affected than Montastrea, and Diploria. Acropora is not affected so far. By 16 October, bleaching was widespread. Earlier some bleaching was reported for the Yucatan coast, but no bleaching was seen near Cozumel. This bleaching event is less severe than in 1995.
(ERIC JORDAN, JUDY LANG, PETER SALE)

Panama

Extensive bleaching was reported in October in western Panama.
(HECTOR GUZMAN)

Puerto Rico

There was no bleaching in 1997. There was, however, moderate bleaching in 1996 after Hurricane Hortense hit the south coast, and all colonies recovered well from partial or total bleaching. In 1998, there has been sporadic but low frequency bleaching in several species down to 30 m deep. The most affected were a zoanthid (Palythoa caribbaeroun), and Millepora, but most other corals were normal.
(ERNESTO WEIL)

St. Lucia

Bleaching in the Soufriere area is the worst ever seen with 100% of all Diploria affected and bleaching in other species including Monrastrea annularis, Porites astreoides, and Agaricia. No mortality has been seen yet, but it is expected.
(ALLAN SMITH)

St. Vincent and the Grenadines

There are second-hand reports of severe bleaching.
(ALLAN SMITH)

Virgin Islands (UK)

Widespread coral bleaching was seen in mid-September 1998 on five reefs south of St. Thomas, which were unaffected in early August. At least 50% of colonies of numerous species were affected, including Montastrea annularis, Porites (branching and massive), Colpophyllia, some Millepora, agaricids, some Siderastrea. But bleaching was patchy with some normal coloured tissue remaining, and there was little evidence of mortality by mid-October. There was moderate bleaching on Virgin Gorda, affecting about 20% of the coral

population. The coral community was healthy and probably recovering from an earlier, possibly more serious, beaching event.
(Les Kaufman, Barbara Kojis, John Ogden)

Atlantic Ocean

Localised regions of warm water were observed in the southern Atlantic Ocean off Brazil in January 1998. Warmer water was then observed off Bermuda in August.

Barbados

A large area of the Carribee bank reef at 25–30 m on the south coast has bleached, apparently in September,1998.
(Renata Goodridge)

Bermuda

No bleaching was observed in May, but it started in early August 1998, and continued into October. Sea-surface temperatures were 28°C in early August and rose to 30°C, and then dropped to 27°C by the end of September. This was abnormally warm for Bermuda (32°N). There was approximately 2–3% bleaching of the 25% coral cover at 8 m on rim reefs, and 5–10% bleaching of 40% coral cover at 15 m on offshore terrace reefs. It was higher on lagoon reefs (2–6 m depth) at about 10–15% bleaching of the 15–20% coral cover. Millepora was most affected, along with some Montastrea. Mortality was low, perhaps 1–2% of affected colonies. Extensive bleaching occurred in 1988 and 1991, with mild bleaching in 1993 and 1997.
(Alan Logan, Robbie Smith)

Brazil

There was mass bleaching on patch reefs off the northern coast of Bahia State (12°S; 38°W) on 14 April 1998. There was bleaching of: more than 60% of Mussismilia hispida (endemic coral); 80% of Agaricia agaricites; and 79% of Siderastrea stellata (endemic). Other corals may have been less affected when water temperatures reached 29.5°C on the bottom of these reefs at 9–12 m, the highest temperature measured during the last three years. By October, all colonies had recovered. On the Abrolhos Reefs (18°S, 40°W) in late April, bleaching was seen in 50% of Mussismilia hispida; 91% of Agaricia agaricites; and 25% of Siderastrea stellata; and six other species showed bleaching of between 25% and 90%.
(Ruy Kenji Papa)

USA (Washington DC)

A colony each of Fungia, Pocillopora damicornis, and Manicina aerolata have remained severely bleached, but not fouled with algae, on desk substratum in the World Bank. Temperatures can exceed 35°C for up to 10 days in August in this hostile environment. An experimental attempt will be made to determine recovery potential by relocating these corals to a new marine aquarium being established by a 6-year-old.
(ANDY HOOTEN)

CONCLUSIONS

The most extensive coral bleaching ever reported has occurred during the 1997–1998 period. There has been bleaching in most parts of the coral reef world and extensive mortality of fast growing, as well as some slow growing corals in places. Some areas have reported bleaching for the first time. However, large areas have not been affected and in other areas there has been widespread recovery of bleached corals.

This event will result in poor coral cover and possibly fewer new coral recruits on many reefs for the next 10 years until recovery gains speed. In the short term, this will impact adversely on the economies of many tropical countries, particularly those reliant on tourism income. If this is a rare event, the long-term consequences for coral reefs around the world are relatively minor. There will be a shift in the composition of coral communities; some will have greater dominance by slow growing massive corals, whereas other reefs will lose century-old colonies. But such shifts have occurred in the past and are part of the normal variability of many coral reefs. If, however, the recent bleaching event is linked to global climate change, and will be repeated regularly in the immediate future, the consequences would be serious for many coral reefs if sea-surface temperatures show a continuing upward trend.

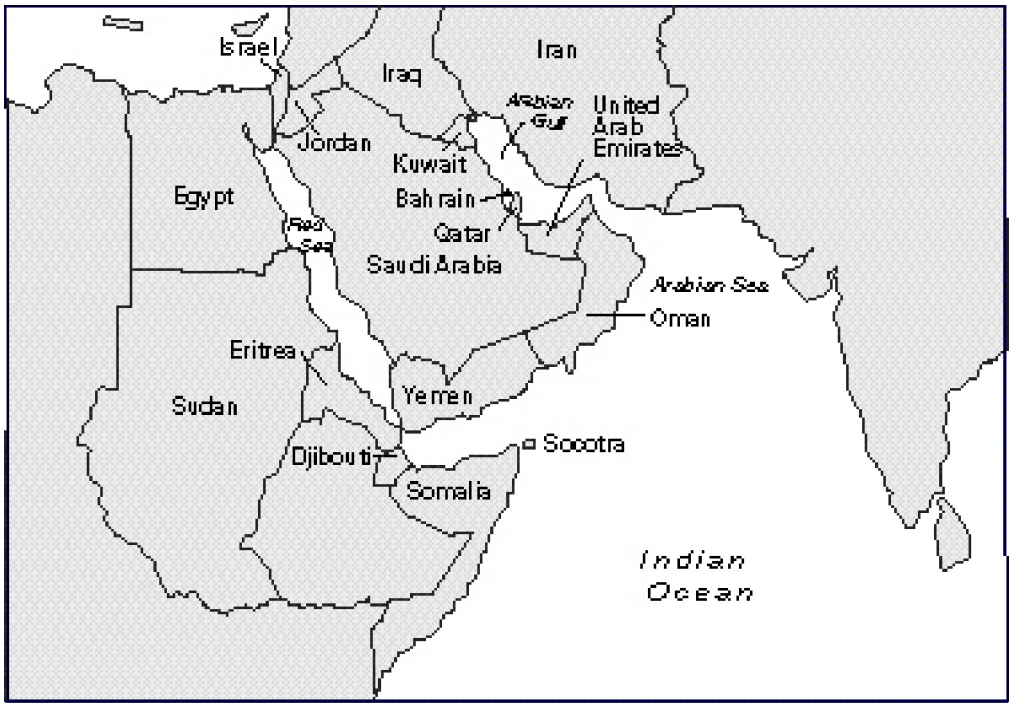
Acknowledgements: Thanks go to all those people mentioned above who provided reports. Special thanks go to Al Strong who provides regular reports on sea-surface temperatures from the National Oceanic and Atmospheric Administration of USA, Jim Hendee who runs the NOAA coral e-mail listing, which has compiled many bleaching reports, and Barbara Brown who provided a summary from the International Society for Reef Studies, which was used as background for much of the Introduction.

2. Status of coral reefs in the Middle East

Moustafa Fouda

Abstract

Coral reefs of the Middle East vary considerably from the well-developed, highly biodiverse, and near-pristine reefs of the Red Sea, to the shallow fringing reefs in high sediment areas of the Arabian Gulf. Between these are reefs heavily impacted by cool upwellings in the Arabian Sea. Middle East reefs are little influenced by runoff from the land, but experience large variations in salinity and temperature. The major human impacts come mostly from the oil and tourism industries, although increasing urban development on the coasts is damaging reefs through dredging and pollution. There is little active coral reef management in the region, although several large projects are developing national management capacity, and targeting particularly valuable tracts of reefs.



INTRODUCTION

This region contains Middle East countries which border the Red Sea (Egypt, Eritrea, Israel, Jordan, Saudi Arabia, Sudan, and Yemen); those which border the Gulf of Aden and the Arabian Sea (Djibouti, Oman, Somalia, and Yemen); and those on the Arabian (Persian) Gulf (Bahrain, Iran, Kuwait, Qatar, Saudi Arabia, and the United Arab Emirates).

This area is very dry, with large seasonal fluctuations in air and water temperatures, and has probably the greatest extremes in tropical marine climates. The reef animals and plants have been selected to survive under these conditions of high stress. As a result of the low rainfall in the region, few reefs are regularly affected by chronic sedimentation from the land. Near the mouths of drainage channels (wadis), there are often breaks in the reefs or coral communities, because flood-waters and sediment prevent reef development.

The Red Sea and the Arabian Gulf are the most saline seas that are linked directly to oceans, because of high evaporation and low volumes of freshwater input. The Arabian Gulf is shallow with a constricted entrance at the Straits of Hormuz. It has large variations in salinity (40–70 ppt). In the Red Sea, salinity averages 36 ppt near the Indian Ocean, to more than 40 ppt in the north. Few coral species can live in areas of very high salinity.

The Arabian Gulf (1000 km by 200–300 km) slopes from the shallow Saudi Arabian side to Iran, 80–100 m deep. The Gulf emptied during the last ice age, about 12,000 years ago, so species that occur there recruited through the narrow Straits of Hormuz. Coral reefs grow in offshore, clear waters near Kuwait and Saudi Arabia in the Gulf. Some fringing reefs have developed at a few sites near the shore, but are generally not well developed due to extreme variations in temperature and light. The rest of the area consists of mud or sand, with some dense seagrass beds.

The Red Sea is a deep (maximum depth 2850 m), flooded rift valley (2000 km by 180–360 km). Coral reefs grow on the continental shelf, which is narrow (15–30 km) in the north and wide (120 km) in the south. The two arms of the northern Red Sea (Gulf of Suez, 255 km by 14–45 km; Gulf of Aqaba, 180 km by 16–25 km) both have luxurious fringing reefs.

Much of the coastline of the Gulf of Aden, Arabian Sea, and Gulf of Oman is sandy or rocky. Coral communities often develop on rocks, but are limited by cold intense seasonal upwellings.

There are few major natural stresses on these reefs as tropical storms do not penetrate into the enclosed waterways, and runoff from the land is minimal. There have been outbreaks of

the crown-of-thorns starfish on Red Sea and Gulf of Oman reefs. On rare occasions, there are extreme low tides (e.g. Gulf of Aqaba) which kill reef flat corals. Many of the human threats to Middle East reefs are shared throughout the region, but are at different levels of intensity, depending on the growth of coastal populations: pollution from towns and industries; oil exploitation and transport; mining and quarrying; and huge power and desalination plants. Increasing quantities of solid waste are being dumped from ships and the land. Reef tourism is expanding with damage from curio collecting and anchors in marine protected areas. Oil pollution, from operational spills and discharge of dirty ballast water, is a continuing threat in the Arabian Gulf and Gulf of Oman.

Middle East reefs provide increasing economic benefits to the people of the region, which can be sustainable, if successfully managed. However, systematic and coordinated efforts to manage these resources are being hampered by the complex politics in this region, weak legal and environmental policy capacity, weak administrations, poor organization, and limited skilled human resources.

The first workshop of the International Coral Reef Initiative (ICRI) in the Philippines in 1995 was attended by only three Middle East states, and by only six states at the Regional ICRI Workshop at Aqaba in 1997. Many countries have received technical and financial help from donor countries, and international organizations, to strengthen their capacity for sustainable management of coral reefs.

Status of coral reefs

Bahrain

The 33 low islands of Bahrain are mostly old limestone with corals (31 species; 19 genera) growing around them. The slopes are gentle with loosely attached corals and little true reef growth. Coral cover is generally less than 10%. The reefs are used by a few traditional fishers, and for recreation. The main human impacts arise from the dumping of dredged sediments, land reclamation, and from oil pollution. The Directorate of Environmental Affairs in the Ministry of Health, and the Bahrain Petroleum Company, are responsible for marine environmental conservation and oil spill contingency plans, but few reef areas are actively protected.

Djibouti

There are a few fringing reefs around several small islands, and some patch reefs in the Gulf of Tadjoura, Gulf of Aden. Little is known of these reefs, although 80 coral species occur on Musha and Maskali reefs. Impacts are primarily from over-fishing, collection of corals and shells, spearfishing, dredging, anchor damage, boat traffic, and resulting turbidity. There is

some tourism, and Maskali and Musha Islands are marine reserves with prohibitions on collecting. There is no active reef management yet. The government has started an integrated coastal management project, including the reefs, with assistance from the Global Environment Facility and the World Bank.

Egypt

The Egyptian Red Sea coast is 1840 km long with extensive fringing reefs facing the Gulf of Aqaba, Gulf of Suez, and the Red Sea. About 205 stony coral species and about 120 soft coral species have been recorded for the Red Sea. The Suez Canal area has about 45 coral species, including some endemic species. Coral cover around northern Red Sea islands is 60–80%, with 20–25% on exposed fore-reef slopes, and in some places soft corals (80%) dominate. Coral cover along the Gulf of Aqaba ranges from 11% to 63%, with higher cover in the south.

The coral reefs are in very good condition, with the only threats being from fishing and tourism. Destructive fishing does not occur, but a few reefs are over-fished, resulting in large numbers of sea-urchins. Tourism results in some curio collection, spearfishing, and anchor damage from dive boats. At one tourist site, coral coverage was 60% only eight years ago, but is now 27%, with anchor damage increasing from 2% to 30%. There have been several oil spills with no significant damage. The reefs are coming under increased management from the Nature Conservation Sector of the Egyptian Environmental Affairs Agency. Areas include the well-known Ras Mohammed Marine National Park (1983) on the Sinai Peninsula, and the Gebel Elba Conservation Area (1986) around the Egypt-Sudan border. Three more parks have been declared recently (Nabq, Taba and Abu Gallum), and two more (Red Sea Islands and Hammata) are proposed for protection.

Eritrea

Reefs on the 1216 km coast of Eritrea in the southern Red Sea are primarily around the Dahlak Archipelago and islands near the coast, many of which are themselves fossil reefs. Reef development occurs usually as thin coral veneers on other substrates, with more developed reefs around the outer islands near the centre of the Red Sea. There is little information on coral abundance and diversity, although surveys have been conducted by the former Ministry of Marine Resources (MMR). The Dahlak Islands are recommended for conservation in an integrated coastal management project in progress with funding from the Global Environment Facility and the World Bank.

Iran

The few reefs that occur on the 2000 km coastline of Iran are near the Arabian Sea, and around islands in the Straits of Hormuz. Most of the bottom has soft sediments with a few

corals. Information is lacking, with Shidvar Wildlife Refuge the only existing protected area that includes areas of reef. The Iranian National Centre for Oceanography conducted a survey of Iran's coral resources during 1998 to assist with national conservation and planning efforts, but the results have yet to be published.

Israel

The short coastline of Israel (14 km) in the Gulf of Aqaba (Eilat) has fringing reefs except near the ports. The reefs are well studied with 99 coral species in 40 genera, and are in relatively good condition, although affected by heavy tourism development. Coral cover on these reefs dropped significantly to about 5% after extreme low tides and oil pollution, but recovered to near 40% in some areas, although not in other areas near the sources of oil and phosphate pollution (still at 15%). The Eilat Coral Reserve (established in 1964) is well managed by the Nature Reserves Authority, which promotes reef conservation.

Jordan

The 27 km coastline of Jordan is similar to the coastline of Israel. There is a discontinuous series of fringing reefs with a narrow reef flat, less than 150 m wide, and a very shallow lagoon and back-reef. The reef front drops rapidly to several hundred meters. Port construction has replaced much reef area, and now tourism development is causing damage through solid waste and sewage pollution. The Aqaba Marine Nature Reserve is not actively managed, but is legally protected. Destructive fishing is illegal, and coral collecting and spearfishing are forbidden. The area is the focus of the proposed Red Sea Marine Peace Park.

Kuwait

Kuwait has very limited reef growth, not exceeding 4 km^2. Isolated corals grow on rocky outcrops, and there are some reefs around offshore cays. All reefs are shallow (to 15 m) with about 33 coral and 100 fish species. Oil pollution and sedimentation cause the largest impacts, and many reefs were impacted during the Gulf War, with some long-term effects of oil pollution. Sewage, outbreaks of sea-urchins, and damage from anchors are other problems. There are no marine protected areas, although some islands are recommended for protection.

Oman

The 2092 km coast of Oman has some coral reef development in four regions: the Musandam Peninsula, which separates the Arabian Gulf from the Gulf of Oman; rocky shores and islands near Muscat; the sheltered western shores of Masirah Island and Barr Al Hickman; and sheltered bays of Dhofar and the Al-Halaniyat Islands. There are 91coral species in 54 genera, with about 200 reef fish species. Coral cover drops from 75% to

40% below 10 m, and decreases to 10% below 15 m. Where suitable substrates occur outside these areas, there are communities of scattered corals with live coral cover approaching 10% in places. The major stresses are dramatic temperature fluctuations (ranging from 18°C to 34°C, with a mean of 27°C, and daily fluctuations of 8–10°C during summer), and crown-of-thorns starfish. Others include infrequent episodic rain, coral bleaching and cancer, black and white diseases, and oil pollution. Tourism is generally not destructive, except for some littering, curio collection and spearfishing. Most physical damage to corals is from fishing gear, particularly nets. Coral bleaching was observed in Acropora and some brain corals. Environmental impact assessments are required for coastal development, and laws prohibit destructive fishing, and protect threatened species. A management plan is being implemented for the Daymaniat Islands, which were declared a marine protected area.

Qatar

High salinity, temperature extremes, and shallow waters limit reef growth around the 560 km long Qatar peninsular in the Arabian Gulf. Reefs are best developed in the east, but are shallow and low in diversity. There is little fishing or tourism, so the major threats are oil, solid waste and sewage pollution, and impacts from coastal developments. Living marine resources are legally protected.

Saudi Arabia

Reefs occur on the 2510 km long Red Sea and Arabian Gulf coasts. The Red Sea coast has extensive fringing reefs on steep slopes, with 194 coral species in 70 genera, and 450 fish species. Most reefs are in excellent condition with only local tourism and limited artisanal fishing, but there are virtually no fishing regulations. Other impacts come from sediment from industrial and urban development, land filling and coastal engineering, with some chemical pollution. The Farasan Islands and Umm Al-Qamari Island are marine protected areas, and moratoriums on development have been approved for another 46 sites.

The Gulf coast has gentle slopes with vast shallow areas of sandy and muddy bottoms, thus there are few reefs. There is more development on the Gulf coast than on the Red Sea coast, with greater impacts from waste disposal, dredging, altered water circulation, pollution, and overfishing. The reefs were damaged by oil and soot during the Gulf War, but are recovering. There is one marine protected area (Jubail Marine Wildlife Sanctuary).

Somalia

There are excellent, highly biodiverse, fringing and patch reefs along the Gulf of Aden coast of Somalia, with a mix of Indian Ocean, Red Sea and Arabian Sea species. These reefs

suffer few natural disturbances and have a high coral cover (more than 90% in places) from the reef flat down to 8 m. There is some shark fishing on the Gulf of Aden coast, but this has had little impact on the reefs. There are no plans for reef protection, but IUCN is working with local administrators, donors, and other NGOs, to monitor fisheries and establish a protected area in the Saad ed Din Islands. There are also reefs near the Kenyan border, but the area is inaccessible, and little is known about the reefs or the threats to them.

Sudan

Much of the 750 km Red Sea coast is bordered by fringing reefs. In the shallow water near the coast, the reefs are from 1 km to 3 km wide. These are separated by a wide deep channel from barrier and platform reefs, 1–14 km wide. The sea floor then drops to hundreds of meters. These are amongst the richest reefs in the Red Sea, with a high diversity of species, for example 71 coral species occur on Sanganeb and Wingate Reefs. There are also dugong and sea turtles.

There is little fishing on Sudan reefs. Limited tourism results in local damage from anchors, waste disposal, and spearfishing. There is some pollution from shipping and land reclamation near Port Sudan. There is one marine park (Sanganeb Atoll Marine National Park), however, management and enforcement are not strong. Sudan is planning to work with Egypt to establish the Gebel Elba Conservation Area.

United Arab Emirates

Many bank and patch reefs, with less than 10% coral cover, grow in shallow water around offshore islands along the 550 km Gulf coast. There is some recreational diving but little fishing, and little is known about these reefs or their conservation.

Yemen

The 500 km of Red Sea coast is shallow, with high turbidity and soft sediments that limit coral growth but favour seagrass beds. About 25% of this shore has fringing reefs or coral communities, with some better developed reefs in the north. But diversity and coral cover (12%) are low.

The Arabian Sea coast has some areas of mixed coral and algal communities with low live coral cover. There are several islands with low diversity fringing and patch reefs (Aden, Mukulla, Bir Ali and Belhaf). Traditional fishing and minimal tourism cause little damage. Destructive fishing and illegal discharge of waste are banned, although sewage pollution may reach damaging levels around coastal towns. Yemen has proposed four areas as marine protected areas, including parts of the Socotra Archipelago.

Marine protection and management

There is often overlap among institutions responsible for coastal management, and there are also ambiguous laws and regulations in most countries. Enforcement is generally lacking, with the exception of well-managed marine protected areas in Egypt, Israel and Jordan, where fishing and tourism are closely regulated. Most other marine protected areas are 'paper parks'.

In the Middle East there are regional conservation plans, supported by the Global Environmental Facility of the World Bank, for Djibouti, Egypt, Eritrea, and Yemen. In addition, the Marine Environmental Initiative Plan and Red Sea Marine Peace Park for the Gulf of Aqaba, the Kuwait Action Plan (The Arabian Gulf, Gulf of Oman, and the Arabian Sea), and the Red Sea and Gulf of Aden Action Plan, all focus attention on problems facing coral reefs. A Strategic Action Program (SAP), focusing on coral reef conservation, was initiated in 1995 by the Regional Organization for the Conservation of the Environment of the Red Sea and Gulf of Aden (PERSGA), with support from countries of the region, the Global Environment Facility, and donors like the Islamic Development Bank.

Recommendations for management

In Middle East countries, there is insufficient research and monitoring, with the possible exception of Israel. This situation could be assisted by establishing networks within compatible countries to standardise methods, implement necessary capacity building, coordinate management, and integrate programmes to raise awareness. Improved monitoring of oil pollution, sharing of detection skills and clean-up mechanisms, will benefit many Middle East countries. These activities and conservation measures will require funding from the oil and tourism industries, and from external agencies and governments with strategic interests in the region. The strong political tensions in the region have hindered a regional approach to coastal management, and this continues, with difficulties in getting better representation at International Coral Reef Initiative meetings.

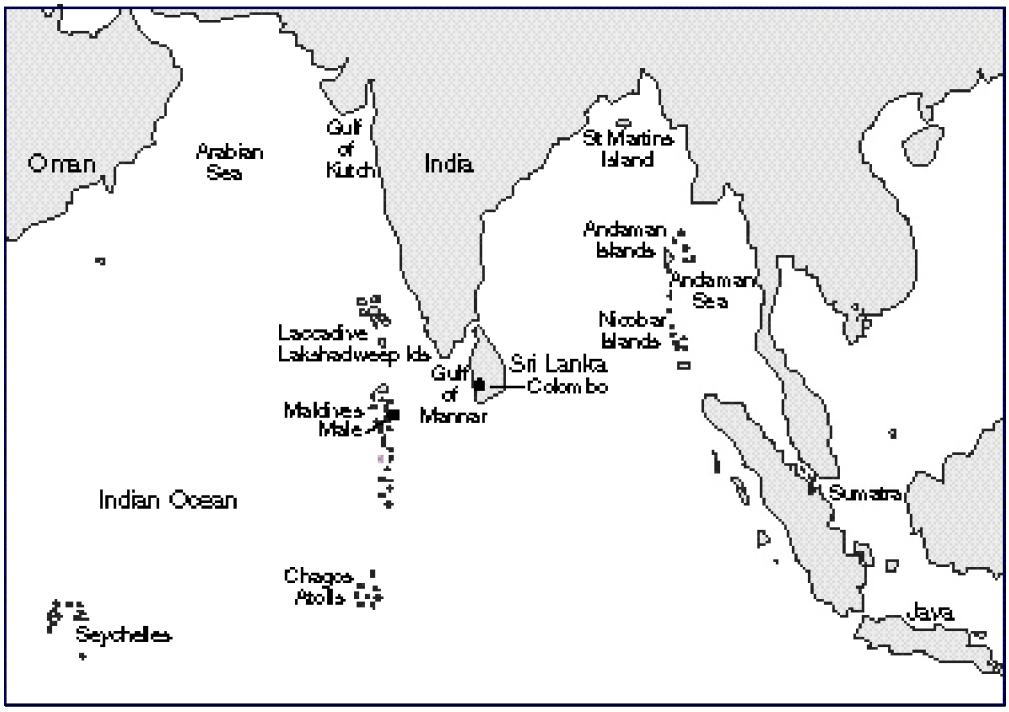
Moustafa Fouda heads the Department of Fisheries Science & Technology at Sultan Qaboos University, Sultanate of Oman. Other advice was obtained from Rod Salm, IUCN Nairobi and Simon Wilson from the Ministry of Regional Municipalities and Environment in Oman.

3. Status of coral reefs in south Asia

Arjan Rajasuriya and Alan White

Abstract

South Asian coral reefs vary considerably. The oceanic reefs (the Maldives, Laccadive/Lakshadweep, and Chagos atolls) and the high islands (Andaman and Nicobar Islands fringing reefs) are generally in very good condition, whereas the fringing and patch reefs off India and Sri Lanka are mostly in poor condition. Increased sedimentation and pollution are major problems on mainland reefs off India and Sri Lanka. Coral mining continues to be a problem in India, Sri Lanka, and in the Maldives. Intensive fishing is common near heavily populated parts of India and Sri Lanka, but less so in the Maldives and the Indian islands. Collection for the aquarium industry is depleting favoured species in the Maldives and Sri Lanka, and tourism is increasing the demand for reef products in Sri Lanka, the Maldives, and the Andaman and Nicobar Islands. Unprecedented coral



bleaching in mid-1998 has seriously damaged almost all reefs in South Asia, with losses of nearly 60–80% of live coral cover. Such large-scale damage, together with natural and human degradation, poses serious problems for coastal communities, particularly for the atolls, which also face a predicted rise in sea level. There is an increase in environmental consciousness, and attitudes towards management in South Asia have risen considerably over the past few years.

Introduction

Most of South Asian coral reefs are off India, the Maldives, Sri Lanka, and Chagos, with very small areas associated with Bangladesh and Pakistan. Coral reef growth off mainland India is mainly in the Palk Bay and the Gulf of Mannar region. Reefs along the rest of the coast are inhibited by massive fresh water and sediment inputs from the Indus, Ganges, and other rivers, and by cold upwelling in the northwest. This is also the reason why there are almost no reefs in Bangladesh and Pakistan. Sri Lanka has shallow fringing reefs and coral growth on sandstone and rocky reefs along about half of its coastline. Over on the eastern side of the Indian Ocean, there are extensive fringing reefs on the mountainous Andaman and Nicobar islands.

The major coral reef structures in this region occur as atolls on the Chagos-Laccadive ridge. This includes the Laccadives (Lakshadweep, India), the Maldives and the Chagos group (British Territory). This group has large areas of relatively unknown submerged coral-limestone banks.

Status of south Asian reefs

Bangladesh

St. Martin's Island (10 km south of the mainland, 8.0 km by 1.6 km) is the only coral reef in Bangladesh. However, it is gradually eroding because of stress from sedimentation, cyclones and storm surges, removal of coral, boat anchoring, and destructive fishing.

Chagos Archipelago

The five atolls with islands of Chagos (21,000 km^2 of shallow waters) are on the southern end of the Chagos-Laccadive ridge, and include the Great Chagos Bank, probably the world's largest atoll, which is mostly submerged except for eight islands on the northwest rim. The military base of Diego Garcia is on one of the smaller atolls to the south.

The Chagos constitute probably the largest area of relatively undisturbed reefs in the Indian Ocean, and some of the best. There are about 200 coral species, including some endemics, which are actively growing. These reefs are reasonably well protected, because they are uninhabited and inaccessible, except for Diego Garcia, but there is no legal

protection. The Corbett action plan for protected areas has identified Chagos as a priority area for the Indo-Malayan region. The only pressures come from fishing boats that are catching sharks for shark fin, and sea cucumbers. This level of fishing is not regarded as a major threat, but there is the possibility that cyanide fishing boats will target the area.

Indian mainland

Coral species recorded for all Indian reefs are 207 in 55 genera. Shallow, fringing coral reefs grow on a few widely scattered parts of the coast. Massive sediment flows from large rivers inhibit reef growth in most areas. In the northwest, the shallow Gulf of Kutch reefs have been heavily damaged by sediment input, sand dredging, and coral mining, and the reef area has declined from 117 km^2 in 1975 to 53 km^2 in 1985. There was a partial recovery of 28 km^2 in 1988, after laws to stop mangrove cutting and coral mining in the Gulf of Kutch Marine National Park were enforced.

The long fringing reef off Palk Bay in the southeast has been badly damaged by sedimentation, pollution, coral mining, and intensive fishing. There are 65 coral species, and some dugong and turtles have been reported, but are under increasing threat.

There are about 20 small islands and many reefs in the Gulf of Mannar, southwest of the Mandapam Peninsula and Rameswaram Island. The marine national park is about 200 km^2, but is not properly managed. The coral reefs here are more diverse than those further north, with 117 species growing in an area more favourable for corals. There is large-scale coral mining, and pollution, and fishing pressure is intense, particularly for dugong and turtle.

Indian Island groups

These are the most important coral reef resources of India. The Andaman and Nicobar Islands in the Eastern Indian Ocean consist of many hundreds of high islands with extensive fringing reefs. These grow immediately offshore from the mountainous islands and are often several hundred meters wide on the Andamans, extending up to 1 km wide in the Nicobars (300 km further south). Recent surveys of 110 locations in 45 reef areas showed that most of the reefs were in pristine condition with up to 135 coral species, and other reefs were degraded due to increased sedimentation, pollution, and destructive fishing. Crown-of-thorns outbreaks have been reported, but there is no information on the impacts. These islands are important for dugong and turtles. The best nesting sites for leatherback turtles in the Indian Ocean are on the Nicobar Islands.

The Laccadive (Lakshadweep) Islands off the southwest coast of India are the northern end of the largest group of atolls in the Indian Ocean. There are 36 islands and lagoons (including 11 major ones), four large submerged reefs and five big submerged banks.

These have the most luxuriant coral growth in India with 69 species, along with giant clams and turtles. Coral mining is present and there is some heavy fishing pressure.

All the coral reefs near the mainland are heavily exploited for coral sand and rock, and there is also extensive collecting of ornamental shells, gorgonians, seaweeds, holothuroids, lobsters, and sea horses. Coral and sand mining are major problems, particularly in the Gulf of Kutch where some reefs have been totally removed. Reef fishing is mostly subsistence and largely unstudied, but may constitute about 10% of the total marine fish catch in India. Pollution and sedimentation are the greatest threats to these reefs, and industrial and oil pollution cause significant damage in the Gulf of Mannar and Palk Bay. Blast fishing and other destructive practices are persistent problems in many areas.

Maldives

The Maldives form the largest part of the Chagos-Laccadive ridge with 22 low atolls, extending 764 km north to south. There are over 800 small vegetated coral islands, and many unvegetated sand cays which cover a 300 km^2 area, but the maximum elevation is only 5 m. Fish are extremely abundant and rich, with about 1000 species. Live coral cover is generally excellent, often exceeding 75%, although recent natural events have affected the health of some reefs. Outbreaks of the crown-of-thorns starfish have caused some coral death, and three periods of higher sea-surface temperatures in 1983, 1987, and 1998 have caused coral mortality, with the recent bleaching being particularly severe. Nothing like this has occurred in the past 40 years of recorded reef assessment, with losses of nearly 80% on many reefs.

Coral rock has been traditionally used as the main building material. For example, about 94,000 cubic meters of rock were mined between 1975 and 1985, and recent estimates are that between 200,000 and 1,000,000 cubic meters of coral rock are mined annually, mostly for resort construction. This coral mining is unsustainable, particularly in the face of future sea level rise.

Tourism is the major reef-related activity, expanding from two resorts in 1972, to 74 resorts in the central atolls. Annual tourist arrivals of more than 200,000 exceed the permanent Maldive population.

Most reef problems in the Maldives are recent (except for coral mining) and result from modernization of fishing methods (providing fish for tourist resorts and the Asian live food fish trade), the development of tourism, and sea level rise. Beaches have been modified, sand dredged, buildings have been set on the beaches, and often methods of solid and liquid waste disposal are poor.

Pakistan

There are no real coral reefs in Pakistan, but in areas where the water is sufficiently clear towards the east, there are often small colonies growing on hard substrate.

Sri Lanka

There are fringing or offshore patch reefs along an estimated 2% of the 1585 km Sri Lankan coastline. There are offshore reefs in the Gulf of Mannar and along the east coast. Corals have also colonised many sandstone and rocky shallow areas, particularly in the southeast, however, the full extent of offshore reefs has not been determined. There are 183 coral species in 68 genera and over 300 species of reef fish in 62 families.

The healthiest reefs are the offshore patch and sandstone reefs, where live coral cover on some reefs (including a few undamaged nearshore reefs), is over 50%. However, most of the nearshore reefs have low coral cover. It is apparent that most of these reefs have suffered extensive bleaching and coral death during the major bleaching event of mid-1998, with losses in coral cover of approximately 80–90% on some fringing reefs along the south coast.

Many Sri Lanka reefs have been severely damaged by human activities. The major impacts are from the increasing flow of sediment from deforestation, poor agricultural practices, and domestic and urban development. Another large impact is coral mining along the southern and eastern coasts. Most reefs are easily accessible, therefore there is extensive fishing, often with explosives or fine mesh nets, and considerable collecting of aquarium species, particularly where law enforcement is absent. There has recently been an increase in uncontrolled tourism development, which is damaging nearshore reefs.

In addition, northwest and east coast reefs are under persistent attack from the crown-of-thorns starfish, and large areas of the coast are naturally eroding because of monsoon waves from the Indian Ocean. Rock and concrete structures have been built to protect beaches, vegetation, and human development, and the threat of sea level rise is a major concern.

Marine protected areas, recommendations for management

There are many **marine protected areas** (MPAs) that include reefs, but most are small, fragmented and without effective management. The best protected reefs are remote from human disturbance (Chagos, Maldives, Nicobars and Laccadives), but few have been declared as MPAs. The Maldives recently established 15 protected sites; India has (1992) several national parks with minimal management; and the Hikkaduwa (1979) and Bar Reef

(1992) marine sanctuaries were established by Sri Lanka, but are ineffectively managed. Most governments have enacted strong legislation for reef management (e.g. in Sri Lanka there is: the Coast Conservation Act [1981, 1988]; the National Coastal Zone Management Plan [1990, 1997]; the National Environmental Act [1980, 1988]; the Fauna and Flora Protection Ordinance [1937, 1938, 1970, 1972, 1993]; the Fisheries Ordinance [1940, 1973, 1997]; and the National Aquatic Resources Research and Development Agency Act [1981]), but resource allocation and implementation are minimal, and do not contribute much to reef conservation.

In most countries, there are ambiguous laws and considerable overlaps among institutions responsible for coastal management, meaning that enforcement is lacking in nearly all countries. Exceptions appear to be in the Maldives, where fishing and tourism are closely regulated in MPAs, but there are no controls in remote areas.

Research and monitoring should be improved and expanded, monitoring methods standardized, and communication links improved among all agencies and countries. This monitoring should include both assessment of the reefs and of the communities that use reef resources. This will increase awareness on the status of, and levels of threats to, coral reefs, and provide resource managers, decision-makers, and funding agencies with valid data.

Capacity building for management is essential in all countries, especially India. Such training can be based on experiences gained in successful and unsuccessful attempts to manage coastal resources. Training should include all aspects of integrated coastal management, including policy development, legal implications, economic values, sociological and biological assessments. It is essential to train personnel to understand the importance of community participation in resource management.

Funding for integrated coral reef management is needed from both country and outside donor budgets. It is essential that programmes for Integrated Coastal Management be funded for the long-term and include all stakeholders, as there are many examples in the region of short-term projects that have collapsed after funding stopped. The involvement of the private sector is essential where tourism developers could be encouraged to lease and conserve nearby reef areas, and introduce eco-tourism to provide tourists with the chance to view healthy coral reefs.

Arjan Rajasuriya is from the National Aquatic Resources Research and Development Agency in Sri Lanka, and Alan White is currently in the Philippines after managing the Coastal Resources Management Project in Sri Lanka.

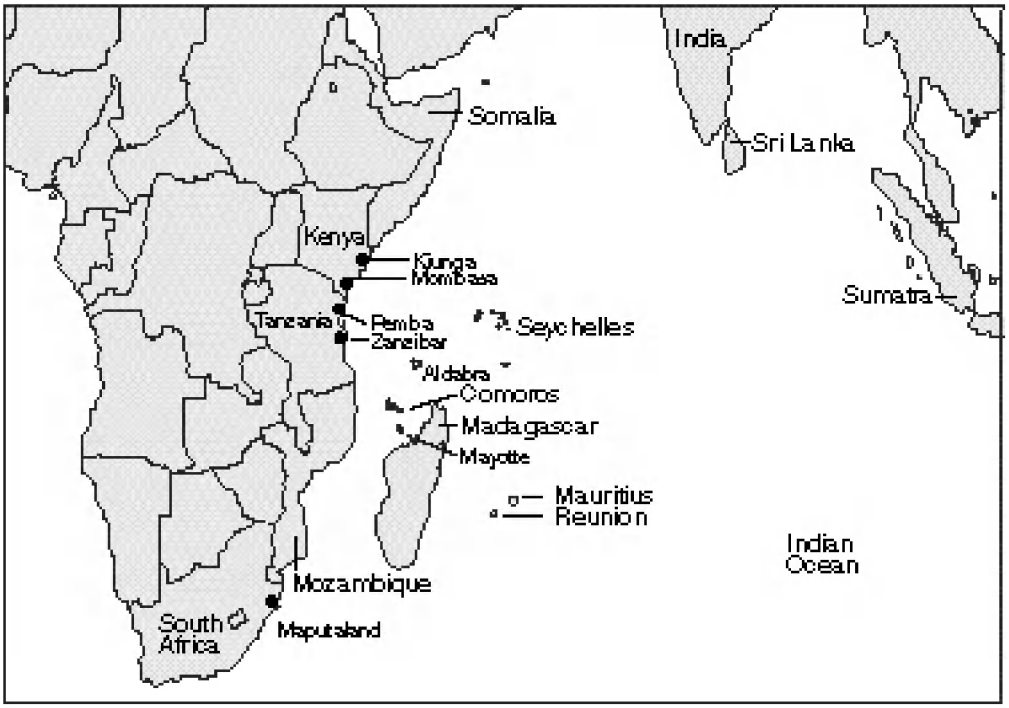
4. Status of coral reefs in the western Indian Ocean and evolving coral reef programmes

Rod Salm, Nyawira Muthiga and Chris Muhando

Abstract

The region has all reef types from atolls to fringing reefs with many endemic species shared within the Western Indian Ocean (WIO), which suggests that the reefs are linked by currents to make this a discrete biogeographic region. This also means there is a need for regional collaboration among the ten WIO states to manage these reefs.

Reef management is not well developed in the WIO, and is focused at the site rather than at national or regional levels. Poorly regulated fisheries and coastal development, together with increasing populations and tourism are major contributors to reef destruction. This is ironic, as both fisheries and coastal tourism are heavily dependent on healthy coral reefs, and make major contributions to the economies of most countries.



Many of the reefs in the region are showing distinct signs of damage from human activities, and bleaching in 1998 has been particularly severe in the Seychelles and Kenya.

The principal reef management activity is the establishment of marine protected areas (MPAs) mainly for tourism, and little is being done to safeguard reefs for biodiversity or fisheries conservation. Although progress is being made in collaborative reef management at the community-government level, there is the need for collaboration among the WIO states to conserve reefs. This will enable sharing of successful approaches for management problems that are common to the region, use of a standard methodology and database for reef assessments to facilitate data sharing and analysis, understanding of processes sustaining the regional linkages, and will facilitate regional collaboration.

INTRODUCTION

The Western Indian Ocean (WIO) countries and states (Kenya, Mozambique, Somalia, South Africa, and Tanzania on the coast; and islands Comoros, Madagascar, Mayotte, Mauritius, Réunion, and Seychelles) extend from 12°N to 29°S, and from the African coast to 65°E. The region has both tropical and subtropical waters with northeast to northwest monsoons from November to April, and southwest to southeast monsoons between June and October. Tropical cyclones occur south of the equator, mainly during the northern monsoon. The major linking current is the South Equatorial Current, which flows west throughout the year at about 12°S, until it hits the African coast where it splits into the southerly Mozambique Current, and the northerly East African Coastal Current. Sea-surface temperatures rarely fall below 20°C, except off northern Somalia during upwelling and off South Africa.

Well-developed fringing and patch reefs occur along the narrow continental shelf of Somalia, Kenya, Tanzania, and northern Mozambique, and around the offshore islands. Reefs off the mainland are broken by the large rivers. The southernmost reefs are at Inhaca Island in Mozambique, just north of South Africa, although coral communities occur off Maputoland in South Africa. Madagascar and the Comoros have well-developed reefs, including barrier reefs off Toliara on the southwest coast of Madagascar, and around Mayotte in the Comoros Archipelago. The Seychelles Bank has reef-fringed granite islands, and patch and fringing reefs around the coral atolls of the Amirantes Bank. The large Saya de Malha Bank, Nazareth Bank and Cargados Carajos Shoals are mostly submerged, and may contain coral communities or reefs. The Mascarene Islands further south have good reefs: Rodrigues and Mauritius have extensive reefs, but not Réunion. Coral diversity decreases in the Indian Ocean from east (Australia) to west, but there are many endemic species.

Threats to coral reefs and associated ecosystems

The threats to coral reefs and their associated ecosystems vary widely between countries, but fall into the following four main groupings.

Resource extraction related activities:

- over-exploitation of living resources;
- destructive exploitation of living resources, including blast fishing;
- coral and sand mining for construction.

Poorly controlled development:

- poor land use practices leading to erosion and sedimentation;
- dredging and/or filling operations;
- tourism-related activities.

Pollution-related activities:

- pollution from land-based activities;
- pollution from maritime transport.

Natural disasters:

- tropical storms;
- coral bleaching;
- Acanthaster planci outbreaks (crown-of-thorns starfish).

The underlying causes for these problems are poverty, and the lack of sustainable income-generating opportunities. Inadequate planning, lack of institutional will or capacity to implement policies and regulations, and civil disturbances, which resulted in the displacement of many people to coastal areas, have aggravated the coral reef management problems. The underlying causes must be addressed to achieve sustainable conservation of coral reefs.

Status of the reefs in countries of the western Indian Ocean

Comoros

The Comoros archipelago comprises four isolated volcanic islands. Fringing reefs are found around Grand Comores, Anjouan, and Moheli. Mayotte (France) is the oldest island in the chain, and has a substantial barrier reef. The Banc de Geyser, in international waters, is a large, horseshoe-shaped reef, submerged at high tide that is notoriously dangerous to shipping. Its isolation has preserved it from human damage.

There are no marine protected areas in the Comoros, and there is one fishing reserve in Mayotte lagoon. The European Union is financing a project on the development of artisanal fisheries, which includes introduction of fish aggregating devices and motorisation of fibreglass boats to disperse inshore fishing pressure to the continental shelf.

The Comorian Government, with the help of UNDP, developed the National Environment Action Plan in 1994 as a national biodiversity conservation strategy, including reef management. A management plan will be developed for the Nioumachoua Marine Reserve to conserve marine turtle nesting beaches as well as some good coral reefs.

Kenya

Along most of the coastline there are well-developed fringing reefs, which have a high diversity of corals and fish, particularly in the four active marine protected areas. Many of Kenya's reefs are, however, heavily fished and degraded, and monitoring studies have shown that coral cover is nearly twice as high on protected, compared to unprotected reefs, and that fish diversity is about 30% higher on protected reefs. Recent coral bleaching has reduced coral cover in the parks by 65%, but studies are continuing to determine the rates of recovery. Kenya has the longest continuous monitoring programme in the region, and has monitored corals, algae, molluscs, sea urchins, and fish in eight reefs over the past 10 years. This monitoring programme has shown a variety of surprising human influences on reefs and has been used to develop models of reef degradation.

Kenya has the best marine protected areas in the region, with four marine national parks and six marine national reserves with coral reefs. Extractive activities are prohibited in parks, though some tourist activities are allowed in certain areas. In marine reserves only traditional fishing by approved methods is permitted. All marine parks and reserves are administered by the Kenya Wildlife Service (KWS) under the Coastal Conservation Project of the KWS-Netherlands Wetlands Conservation and Training Programme, which is actively improving site management. Kenya is moving increasingly towards direct community participation in MPA management.

The WWF and KWS are collaborating to enhance management of Kiunga Marine Reserve, a biosphere reserve off the north coast of Kenya. This began in 1996 and focuses on conserving the outstanding biodiversity, natural resources, and ecology of the reserve through consensus-based management with the full participation of local communities. The plan aims to improve the livelihoods of neighbours and users of the reserve.

The Coral Reef Conservation Project is a field programme of the Wildlife Conservation Society (previously the New York Zoological Society), and conducts monitoring and research with

scientists from KWS and Kenya Marine and Fisheries Research Institute on the status of coral reefs, and threats such as fishing, shell collecting, sedimentation, and pollution. This project has been active in determining the rates of recovery of reefs recently protected from heavy fishing, and has worked on a variety of methods to restore degraded reefs.

Madagascar

There are numerous reefs around the island, with those on the east coast being the least known, including fringing reefs near Antseranana to the Iles de Leven; fringing coral growth around Nosy Borah (Ile Saint-Marie); and a submerged, fragmented barrier reef off Toamasina, with a reef flat covered by seagrasses. The west coast has more than 1000 km of reefs, located in the northwest and southwest. These reefs have suffered significant damage from sediment runoff as most of the forests have been cleared for timber, and slash and burn agriculture. Fishing pressure is intense on many reefs.

There is one marine park (Nosy Atafana Marine Park) and one special reserve (Nosy Mangabe Special Reserve) that includes reefs, but neither are effectively managed. Most marine conservation effort is currently going into the Grand Recif at Toliara. Considerable reef research was undertaken by French scientists from the 1960s to mid-1970s. In 1992, local scientists and the WWF, surveyed the Grand Récif at Toliara and recommended conservation. The Universite de Toliara is active in marine research and multidisciplinary reef surveys. A marine and coastal conservation programme for Madagascar was identified as a priority by the WWF in 1996. The programme includes coastal surveys, and assistance for Malagasy authorities to develop a comprehensive system of coastal and marine reserves to conserve coastal resources, including reefs. The WWF programme complements a UNESCO project to manage the extensive Grand Récif at Toliara, off the southwest coast, as a protected area and biosphere reserve.

Mauritius

The central island is in the Mascarene group, and almost entirely surrounded by fringing reefs. More fringing reefs border the channels and protected bays, with patch reefs in the lagoon. The other island, Rodrigues, is older with well-developed coral reefs (200 km^2). The Cargados Carajos Shoals are about 190 km^2 of reefs and a massive algal ridge — possibly the largest in the Indian Ocean.

The reefs have been badly damaged by overfishing, tourism and development activities, and inactive reef management. Runoff from sugar cane farming is a major problem for reefs in the lagoon. The Mauritian authorities are working with the University College of North Wales to classify and map the coral reefs, and plan for two reef reserves that were originally proposed in 1974.

A series of reefs were prepared for management, with replanting of mangroves and establishment of nurseries, and studies of physical, chemical and biological parameters of lagoon waters influenced by sewage and industrial discharges. A Marine Environment Management Plan was prepared by the Ministry of Fisheries and Marine Resources. The Ministry is also monitoring the reefs and establishing two marine parks to conserve reefs, including:

- banning the removal and sale of shells and corals, whether live or dead;
- banning spearfishing;
- tight control on the use of explosives;
- closed seasons for seine net fishing; and
- establishment of fishing reserves.

Between 1991 and 1994, there has been baseline data collection of reef and water quality at several sites around the island, and lagoon water circulation patterns were studied at Albion as an example of coastal and lagoon water flows. Other lagoon and reef studies are being implemented with technical assistance from Japan through the fully equipped Marine Conservation Centre at Albion.

Mozambique

Reef development on the Mozambique coast is limited by freshwater and sediment flows from the large rivers. Reefs are found at Inhaca Island, near the South African border; the Bazaruto Archipelago; and the Primeira and Segundo Islands. Fringing reefs are found close to shore from Macambo Bay to the Tanzanian border.

Ilhas da Inhaca e dos Portuguesas and the Bazaruto National Park are two protected areas with significant coral reefs. WWF has been supporting the community-based management of Bazaruto National Park with European Union funds since 1989. The management plan expands the emphasis on community-based resource management to conserve the fragile Bazaruto Archipelago ecosystem and improve the socioeconomic conditions of island communities.

The Oceanographic Research Institute in Durban, South Africa, in association with the World Bank and the IUCN, has surveyed the reefs around Bazaruto Island for a Park management plan, and a handbook on the island.

La Réunion

This active volcano is the youngest and highest of the Mascarene islands, and has relatively little reef development. The other island dependencies of Réunion are spread over a wide area of the Indian Ocean and Mozambique channel: Tromelin (north of Réunion), the atolls Europa and

Bassas de India in the Mozambique Channel, Juan de Nova off the west coast of Madagascar, and the Iles Glorieuses to the north of Madagascar. They are coralline islands with some reef development, and all are declared protected areas with Juan de Nova replaced by Bassas de India under later legislation Réunion has ratified the Nairobi Convention.

The Laboratoire d'Ecologie Marine of the Universite de la Réunion has done considerable research since the 1970s on coral reef populations and processes, and management and exploitation of reef resources. Much research is on anthropogenic impacts on coral reefs, especially the effects of reduced water quality on coral calcification rates. An active programme to involve school students is under way to ensure that the next generation has a reef conservation ethic.

Seychelles

There are 115 islands scattered over 1,374,000 km^2 of ocean. Fringing reefs are dominant on the central granite islands, and numerous patch reefs and coral islands on the outer banks. There are raised and sea level coral atolls with well-developed coral reefs. The best known is Aldabra Atoll, a World Heritage Site. Human impacts on the reefs are generally slight, but fishing pressures are increasing. Tourism is a major industry based around the reefs. The 1998 coral bleaching event has caused large-scale mortality of many shallow corals.

The Seychelles have a comprehensive system of marine parks and reserves. The Division of Environment, with technical assistance provided by IUCN, is implementing two protected area projects with a focus on coral reef conservation: Rehabilitation of Curieuse Marine National Park (with funding from France), and a country-wide biodiversity conservation and national parks programme (funded by the European Union). The Fisheries Act and Regulations 1986/87 prohibit blast and spearfishing, and are enforced by the Seychelles Fishing Authority.

A reef monitoring programme has been set up with training funded by Sweden (SAREC), and assistance from the Great Barrier Reef Marine Park Authority. Through the Indian Ocean Commission, the Seychelles are implementing a project to:

- prepare a bibliography of all information on Seychelles coral reefs;
- identify sensitive coral reef areas being degraded around Mahé, and establish monitoring using IUCN rapid assessment methods;
- identify other coral reefs around the inner granite islands for protection; and
- identify reef sites for restoration.

Somalia

Reef growth is inhibited by cold upwellings off the northern coasts of Somalia, but there are fringing reefs between 0.5 km and 1.5 km off Adale to the Kenyan border, coming close to shore near Kismayo. There are coral islands and reef flats in the Bajuni Archipelago near the Kenyan border. The only major break in the barrier reef is off Mogadishu, where there are a few patch reefs with seagrass beds. The coral reefs are poorly known with no marine protected areas, nor any activity to conserve the reefs. IUCN is working with the Somaliland administration to develop management options for the coral reefs along the western part of the Gulf of Aden coast, particularly near the Saad ed Din Islands near Djibouti. These northern reefs are in excellent condition, and rich in biodiversity because of their proximity to the Indian Ocean, the Red Sea, and the Arabian Gulf.

South Africa

There are no true coral reefs, but there is a 65 km stretch of coral-covered rocky reefs off Maputoland (KwaZulu/Natal), between Ponto do Ouro on the Mozambique border and Cape Vidal. These reefs are remote from the large industrial areas and the influence of runoff from rivers, therefore they are largely unspoiled, and are protected as the St Lucia Marine Reserve. The area is used intensively by recreational divers, but is well managed by the Natal Parks Board and is being monitored by scientists from the Oceanographic Research Institute (ORI) in Durban, in collaboration with the University of Tel Aviv. The scientists are examining reef damage caused by human use and other disturbances (including a small crown-of-thorns outbreak) and have recommended a zoning plan for long-term reef use that emphasises ecotourism and reduces diver damage. Artisanal fishing is permitted in much of the reserve and local communities are gaining increased benefits from ecotourism through direct employment, and the development of secondary industries. A management plan is being developed for Aliwal Shoal. This is an island community of corals and associated fauna off the south coast of KwaZulu/Natal that is used by anglers, spearfishermen, and is a popular dive site.

Tanzania

There are fringing and patch reefs along two thirds (600 km) of the narrow continental shelf. The many patch reefs are often extensions of fringing reefs and develop away from river mouths. The continental islands of Mafia, Zanzibar, and Pemba, along with many other small uninhabited islands are surrounded by fringing reefs. The Department of Fisheries regulates all fishery activities, but has not been successful at controlling blast fishing and destructive forms of seine netting. The reefs are also being damaged by sediment runoff from increasing agriculture and coastal development.

In 1981, Tanzania gazetted a number of MPAs, but these exist only on paper. However, the Institute of Marine Science in Zanzibar, the WWF, and Frontier are assisting Mafia Island communities in the design and development of Mafia Island Marine Park, the first in Tanzania under the Marine Parks and Reserves Act, 1994. Mafia Island has some of the best coral reefs on the African coast, and the Fisheries Division and the WWF are developing a management plan with strong community participation, which will provide them with direct benefits. The Department of Environment, the Institute of Marine Science, and Sub-commission of Fisheries are actively promoting reef management in communities on Zanzibar, and transferring the successes to other sites. The Chumbe Island Reef Sanctuary in Zanzibar is an experiment in reef management by a private company. Collaboration between the WWF, government, and local communities has developed a multiple-use, community-managed marine conservation area in Menai Bay, southwest Zanzibar. The Kunduchi Marine Biological Station has a programme of reef fisheries research.

The Swedish government (SAREC and Sida) is supporting national coral reef surveys and research through the Institute of Marine Science. Integrated coastal management is being developed for the Kunduchi area of Dar es Salaam on the mainland to address the critical problems of reef pollution and blast fishing. In Tanga, northeast Tanzania, the Regional and District Government Authorities are implementing integrated coastal management focused on coral reef restoration and community-based management with assistance from IUCN and Irish Aid. This is a test case in community-based management and restoration by controlling blast fishing and the use of weighted seine sets.

Coral reef management in the western Indian Ocean

Reefs in the region are probably all linked closely by ocean currents that carry larvae, migratory species, nutrients, and pollutants across national boundaries. Destruction of the source of larvae on one reef may impoverish others down current, therefore an understanding of source-sink relationships is essential for long-term reef management. MPAs are more likely to be located for the tourism industry, than to conserve reef larval resources. Little knowledge is available on the sources, circulation patterns, fates of pollutants, and effects at national and regional levels. Little is known on the links between coral reefs, mangroves, lagoons, and seagrass beds in the region. Successful management also requires information on reef status, and human uses and threats. Above all, there is a fundamental need for community involvement in reef management and the incorporation of traditional management systems, user rights, and socially acceptable alternatives to reef fisheries.

Capacity for research and training

Until recently, there was little capacity for marine research and management in the region. Most interest was from outsiders who had little interaction with local researchers. Now there are many more competent nationals, but there is a great lack of funds, equipment, and infrastructure for national research institutions, and national funds are unlikely to be diverted away from poverty alleviation and development. Institutional budgets barely cover salaries, therefore donors are urged to provide relevant equipment, encourage regional collaboration to maximise the effects of the limited resources, and encourage partnerships between international scientists. Offers of training should be pertinent to national problems. Training in integrated coastal management is essential, with emphasis on multi-disciplinary approaches involving ecology, economics, law, and other social sciences.

Approaches to conservation of coral reefs and their associated ecosystems

The traditional approach for reef conservation of village-imposed closed seasons or areas, such as for octopus and some fish around Zanzibar and Tanzania, have been eroded and replaced by MPAs. Protected areas can be valuable management tools to balance the effects of exploitation elsewhere and improve fishing yields nearby, but these require good planning and adequate resources for maintenance. But MPAs alone are not adequate for long-term management of reefs because they seldom address threats from land-based activities. Without full community involvement, MPAs cannot resolve user conflicts, nor address the resource needs of coastal communities. Reef conservation will require an integrated management approach that includes land use planning, pollution reduction, fisheries management, user conflict resolution, environmental education, protected area management, and the capacity to respond to environmental disasters. Regional coordination is needed to safeguard circulation of larvae, nutrients and migratory species, and to maintain water quality. Community management of coastal resources is the focus of increased attention in Kenya, Zanzibar, and Tanzania by IUCN and the WWF, but conflicts between different government sectors can only be resolved when higher levels of government are aware of the problems, possible solutions, and the need for immediate action.

INTERNATIONAL AND REGIONAL CORAL REEF PROGRAMMES

The International Coral Reef Initiative brought all of the states together in March 1996 to develop a coherent program for reef management. Countries observed that they shared common problems and investigated common solutions. Currently, coral reef regional activities are being undertaken through: UNEP Eastern Africa Regional Seas Programme; Indian Ocean Commission (for the island states); WWF and IUCN; IOC/UNESCO; Coastal Resources Center, University of Rhode Island; with aid from Ireland, the Netherlands,

Sweden, and USA, with participation from the Western Indian Ocean Marine Science Association (a regional NGO supporting reef research).

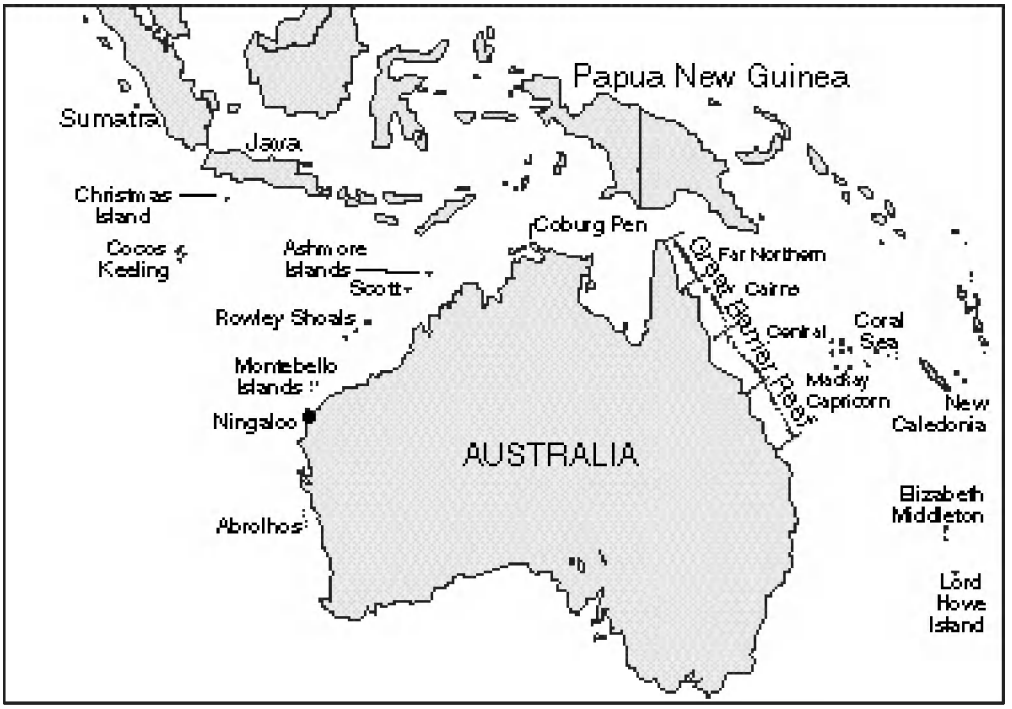
Rod Salm is from the IUCN Eastern Africa Regional Office, Nairobi, Kenya; Nyawira Muthiga works with the Kenya Wildlife Service, Mombasa, Kenya; and Chris Muhando is from the Institute of Marine Science, Zanzibar, Tanzania.

5. Status of coral reefs of Australia: Great Barrier Reef and western Australia

Terry Done and Clive Wilkinson

Abstract

The major stresses to Australian reefs are natural, such as cyclones, coral bleaching and crown-of-thorns starfish. Human stresses are minimal, except on some reefs close to the land, because population density is low, the economic status is high, and there is low fishing pressure. Major research is now under way to ensure that fishing is sustainable for target species, for the total catch taken, and for the health of the reef ecosystem. All Australian reefs are under efficient management with strong local support, and good compliance which has achieved more by education and involvement, than by strict enforcement. The bulk of the Great Barrier Reef (GBR) is in good condition because most of it is remote from land influences, but inner shelf reefs may have suffered impacts resulting from increased sediment and nutrient runoff caused by cattle grazing and sugar-cane



growing. However the farming industry is working to reduce impacts out of both self interest and concern for the environment to minimise sediment and nutrient runoff into GBR waters. Most towns along the coast are upgrading sewage treatment to secondary level and all tourist resorts are now required to treat sewage so as to avoid any runoff, and to manage the areas of reefs that they use. Reefs off western Australia are in good health as they are generally not impacted by land influences, and there have been no impacts attributed to petroleum exploration or fishing. There is strong recognition by government that the tourism and resource values of coral reefs are particularly high, which means that management receives sufficient attention.

INTRODUCTION

Australia has more reefs under its control than any other country. Most reefs form part of the Great Barrier Reef (GBR) which is probably the best known reef system in the world. All of the GBR is now incorporated in the Great Barrier Reef Marine Park, which contains about 2800 separate reefs along about 2000 km of coastline in an area of 350,000 km^2 of broad continental shelf. The GBR is not just a barrier reef, but a complex pattern of barrier, platform, patch and fringing reefs growing on the Australian continental shelf, which is narrow (less than 20 km) in the north, broadening to over 100 km in the south. These reefs have very high diversity with about 350 species of coral (compared with the maximum of about 450 species in Indonesia) and estimates for fish species vary from 1200 to 2000. There are also extensive areas of coral reefs in the Coral Sea between New Caledonia and Australia.

Off the western coast of Australia, the reefs are not nearly as extensive and abundant as on the GBR, but cover a range of types including mainland fringing reefs such as Ningaloo, oceanic reefs in the Timor Sea and Indian Ocean such as Cocos-Keeling and Christmas Islands, shelf-edge reefs such as Rowley Shoals, Ashmore, Scott, Seringapatam, and island reefs such as Kimberley, Dampier Archipelago, Houtman Abrolhos.

There is little reef development along the northern Australian coastline, which has a relatively low population, but there are numerous fringing reefs around islands and coral growth on hard bottoms. However, there are some pressures, including commercial fishing, prawn trawling and traditional use.

On average, the major stresses to virtually all of these reefs are natural as human pressures are relatively light. The Australian continent has the lowest population density of any large area on earth (with the exception of the Antarctic) and few of these people live near the

tropical coastal areas. The reefs of Australia are generally in good to excellent condition, and the major factor to keep them that way is strong management of virtually all the reefs around the continent and strong public support for reef conservation.

Australian reefs, particularly the Great Barrier Reef, are critical refuges for dugongs and sea turtles, as populations of these endangered animals are being greatly reduced in waters to the west, north and east of Australia through subsistence and commercial harvesting. There are significant populations in Australia for four out of the six major species of turtle, which are threatened elsewhere in the world by unsustainable levels of harvesting. The sheltered reef waters are major breeding grounds for humpback whales. Conservation of these animals forms a major priority in government plans for the management of coral reef resources.

The distribution and abundance of most of the major animals and plants is well known on the GBR and, to lesser extent, on other reefs. Other than Hawaii and Florida, this is a rare situation for coral reefs around the world. Few of the major resources are threatened and populations appear stable.

Natural pressures on Australian reefs

Cyclones occur relatively often on both sides of Australia and cause major local damage to coral reefs. In addition there is considerable fresh water runoff, with increased sediment and nutrients as a result of these cyclones on the east coast. The crown-of-thorns starfish and coral bleaching have caused major damage to Australian reefs in the past 30 years and currently the reefs are recovering from a major bleaching event this year. Some reefs close to shore were severely impacted with high coral mortality, but most reefs suffered only minor damage.

Although most of the reefs of the GBR are a long way offshore, sediment and nutrient pollution are the major threats to the inner reefs. The largest sources of sediment are from two major rivers that drain large areas of dry, cattle-grazing lands, as well as many shorter coastal rivers that carry flood waters during wet seasons. Heavy rains after drought have resulted in major outflows of sediment into the GBR Lagoon (the waters between the reefs and the coast, an area 2000 km long by 20–100 km wide), which damages inner and possibly affects some middle-shelf reefs. The farming industry is developing practices to reduce their own soil losses and at the same time reduce damage to the reefs from excess sediment runoff. This situation does not arise off the western coast of Australia where there is scant agriculture and particularly low rainfall on the land adjacent to the reefs.

Human pressures on Australian reefs

Human pressures on the reefs are low, because the population density is low, the reefs are mostly remote from the coast, and fishing pressures are moderate to slight and in some areas virtually non-existent. For example, the offshore atoll reefs on both coasts are so remote from the mainland influences that they are only subject to occasional fishing for prized target fish.

The major sources of nutrient pollution (nitrate and phosphate) on the GBR are from cattle grazing, cane and banana farming, domestic sewage, and tourist activities in that order. Vigorous education and extension programs run by the Departments of Agriculture and the reef managers have raised awareness and led to improved practices in the rural sector. Unmanageable delivery through extreme flood events may be the major source of sediment and nutrient pollution. Cane and banana farmers are regulating their use of fertiliser to minimise runoff loss. Most farmers, including many who are also keen fishermen on the reefs, have changed to green tillage of crops (leaving the trash on the ground as compost and not burning crops). This can reduce sediment loss from cane fields by 20 to 100 times. All tourist resorts treat sewage so that there is no pollution (tertiary treatment).

There is some subsistence fishing on the remote reefs off Western Australia; some is permitted under agreements between Indonesian and Australian governments; but in other areas, there are continuing problems (mostly legal and political) of small-scale poaching of shark, fish, trochus, giant clams and sea cucumbers.

The Great Barrier Reef (GBR)

The status of the GBR can be summarised using the four sections in the original declaration of the GBR Marine Park in 1975. Each section is huge and contains hundreds of coral reefs, thus comments on reef condition are based on observations of a small proportion of the reefs. About 20% of the more than 2800 catalogued coral reefs in the GBR are submerged reefs or shoals, while about 26% are fringing reefs around continental islands or along the mainland coast. The remaining reefs are typical carbonate rock platforms rising up from the continental shelf.

Corals and reef fish have been well studied on the GBR, showing that coral cover decreases and then increases quite dramatically after cyclones, crown-of-thorns starfish and coral bleaching, but there are no long-term declines in coral cover or diversity. Even on inshore fringing reefs, where human impacts are highest, there are no indications of any general decline over the last 10 years.

Most coral reefs have about 30% coral cover on average, and rarely do reefs exceed 60% coral cover. This is a result of normal variations and natural 'wear and tear' on the corals and reefs. Coral cover on inshore reef slopes at 5 m varies from 50% to 90%, whereas the reef flats are frequently dominated by macroalgae (particularly Sargassum) and about 5% hard coral cover. Coral cover on offshore reef flats is often higher than on nearshore reefs, but cover on slopes is lower (average 29%). Reef fish populations fluctuate naturally because of changes in annual recruitment. Studies do not indicate any long-term major impacts from line fishing on reefs.

The Mackay Capricorn Section — South

This section extends over 400 km from Proserpine (21°S) to Bundaberg (around 24°30'S) and contains several hundred coral reefs ranging in size from less than 1 km^2 to over 200 km^2. Most (around 90%) of the reefs are more than 100 km offshore. The reefs in the north form a dense, complex, and reticulate matrix, while in the south, the reefs are small, discrete and very open to oceanic influence. There is major commercial and recreational fishing with no apparent damage to the reefs or fish populations. The sea floor is trawled for prawns and scallops. The effects of fishing on target fish, bycatch and the ecosystem are being studied.

The adjacent coast is a diverse mix of wetlands, lowland sugar-cane farms and lowland and upland grazing, as well as several ports and towns. These activities may influence the amount of sediment and nutrients flowing into this section of the GBR, but the dominant influence on the nearshore reefs are the strong tide and wind currents and waves that regularly re-suspend the bottom sediments and spread them over the continental shelf. There are many coral reefs that are adapted to growing in this turbid water, and these vary with time, depending on the major floods. In 1990, a major flood of Queensland's second largest river — the Fitzroy caused localised coral death on nearshore island fringing reefs that has been slow to recover.

Cyclones are common in this section, but surveys indicate that the outer reefs have consistently high coral cover, the highest for the whole GBR. Crown-of-thorns starfish have caused localised reductions in coral cover on some reefs in the north and south over the last 20 years and major bleaching of shallow corals occurred on some offshore reefs in early 1998.

The Central Section

This section starts near Innisfail (17°S) and extends for 400 km to Proserpine (21°S). There are several hundred coral reefs ranging from less than 1 km^2 to over 200 km^2 with around 90% of reefs more than 50 km offshore in a matrix that is very open to oceanic influence. Major commercial (including bottom trawling for prawns and scallops) and recreational

fishing apparently has little damaging effect on the reefs. There are ten coral reef no-fishing, no-collecting areas up to 100 km^2 in area, and the effects of reef fishing on target fish, bycatch and the reefs are being checked.

There is a mix of rich wetlands, agriculture (lowland sugar-cane farming and extensive upland grazing) and developments, including the port city of Townsville and several smaller towns. These activities have added considerable sediments and nutrients to the waters, but there have been only minor effects on coastal reefs. Coral reefs grow in these nearshore turbid waters, except around Queensland's largest river, the Burdekin, and these reefs are well adapted to resuspended sediments. There are many tourist resorts and much boating activity in the Whitsunday Islands, and management is designed to protect the reefs while allowing reasonable access.

Cyclones and crown-of-thorns starfish caused major reductions in live coral cover in the last two decades. High densities of the starfish began in the north in the early 1980s and progressed southwards by larval dispersal by the mid- to late-1980s. There was high coral mortality and reductions in coral-feeding fish. But there was strong re-growth of fast growing corals and coral-feeding fish in shallow water, but deeper slopes and areas dominated by slow growing corals are recovering more slowly. A new outbreak of the starfish is now starting in the northern section, and major coral bleaching in 1998 caused high mortality in shallow parts of middle shelf, nearshore and island fringing reefs north of Townsville.

The Cairns Section (North)

This starts north of Lizard Island (14°S) down to Innisfail (17°30'S), and contains several hundred reefs from small (1 km^2) to large (over 100 km^2) along the 400 km section. The mid-shelf part is a dense, complex matrix of reefs sheltered from ocean waves by an outer barrier reef, broken only by narrow passages. There are 30 preservation zones (no-take areas) up to 75 km^2, mainly on reefs. The continental shelf is narrower and about 90% of the reefs are within 20 km of the coast. This area is heavily used by tourists, and is extensively fished commercially and recreationally.

The coastal plain is narrow with large areas of sugar-cane farming, adjacent to an extensive world heritage area of rainforests on low mountain ranges. Beyond this there is extensive upland agriculture and grazing in the water catchments. The Great Barrier Reef's major tourism centres for day trips and live-aboard trips to the reefs are Cairns and Port Douglas. Nearshore reefs are limited in number and extent because of high rainfall and moderately high human population densities, and the corals have been damaged by increased sediments and nutrients coming from the rivers. Reefs in the middle of the section were

impacted by sediments from a controversial rainforest road built in the 1980s, but there is no evidence of major long-term changes. In the far north are major silica sand dunes that provide a less turbid nearshore environment.

Cyclones are common, and crown-of-thorns starfish have caused reductions in live coral three times in the last 30 years, each time followed by strong coral recovery. The major tourist reefs were either not affected or were protected by starfish collection programs after early warning from government reef monitoring programs. In the southern half, coral cover on 31 reefs declined from the high 20%s to the low 20%s from the mid-1980s to mid-1990s, in parallel with increases in starfish of from 5% to 40%. However, coral cover increased in the northern half of the section, despite similar numbers of starfish. This is probably the 'primary outbreak' region for crown-of-thorns starfish, because all recent outbreaks were first recorded here. This leads to the suggestion that the outbreaks may be due to human activity because this section has the greatest amount of human activity, and the highest runoff of sediments and nutrients, and these factors may mean that more larval starfish survive, or more starfish predators are removed by fishing. New outbreaks of the starfish occurred in mid-1998. Nearshore and island fringing reefs in the southern part of the section were bleached in early 1998, some with high coral mortality.

The Far Northern Section

This starts at the tip of Cape York (10°40'S) and extends over 400 km to Lizard Island (14°S), and contains several hundred reefs ranging from small to large. The continental shelf is narrow and around 90% of the reefs are less than 20 km from shore. There is a dense matrix of reefs sheltered from the ocean by an outer barrier reef with narrow passages. In the north (10°S to 13°S), the shelf is over 100 km wide and mid-shelf reefs are more exposed to ocean waves. The land is almost uninhabited with a small amount of cattle grazing and the rest of the coast is either muddy or sandy. There are virtually no tourists and little recreational fishing and diving, but there is significant reef-line fishing and sea-floor trawling.

This section includes the largest no-take area in the GBR Marine Park (more than 5000 km^2 and across the full 140 km width of the continental shelf). There are also another 20 no-take areas (10–400 km^2). Surveys of 30 reefs showed differences between the north and south in the 1990s: low and declining abundance of crown-of-thorns starfish and a high and increasing coral cover in the north; and low abundance of starfish and coral cover declining from mid-30% to mid-20% in the south. Aerial surveys of the 1998 bleaching event indicate most inshore reefs had low levels of coral bleaching while most mid-shelf and offshore reefs had none.

Coral Sea Reefs

There are a series of atoll-like reefs on a deep shelf between Australia and New Caledonia. These atolls sit in very deep clean water and are under the influence of strong oceanic waves and cyclones. Some reefs have coral cays, which are all uninhabited except for a weather station. The reefs are remote from any land influences and have only minor fishing pressures, and are in virtually pristine condition. Populations of giant clams were heavily poached by ships from east Asia in the 1980s, until enforcement by Australian authorities increased.

Lord Howe Island and Elizabeth and Middleton Reefs

Lord Howe Island (31°40'S) has one of the most southerly coral fringing reefs in the world. This volcanic island (14.55 km^2) is 603 km off the east coast of Australia and has fringing reefs with low species diversity, but a good coral cover on the rocky slopes, in passes and lagoons. The island and surrounding seas were declared a World Heritage Area in 1982. There were significant differences in the composition of coral species between 1978 and 1993, suggesting some turnover of rare species. The reef has been subject to crown-of-thorns starfish predation (early 1990s) and coral bleaching (late 1990s), but impacts have been minimal and the condition of the reef is good. Fish, plants and invertebrates have a mix of tropical and temperate species and a number of endemic species. There is a management plan to protect the area's World Heritage values while allowing recreational fishing, and fishing to supply locals and tourists.

Elizabeth and Middleton Reefs are large atolls situated about 120 km north of Lord Howe Island. Surveys in the 1980s and 1990s showed there was more diversity and more tropical species than on Lord Howe. Crown-of-thorns starfish did some damage throughout the 1980s, but the full impacts are not known. Human impacts are negligible, but storms and occasional shipwrecks do have local impacts.

WESTERN AUSTRALIA

Ashmore Reef, Scott Reef and Rowley Shoals

These isolated oceanic and shelf-edge reefs are far from any mainland influence, being scattered between 12°S and 18°S along a line 400 km from the northwest Australian coast. Ashmore Reef (12°S) is closer to Indonesia than Australia and is regularly fished by Indonesians under conditions agreed by both governments. Scott Reef (14°S) is visited less frequently by Indonesians, and is a prospective site for extraction of liquid natural gas. Rowley Shoals (17°S) are protected as State and Commonwealth marine parks. Trochus, trepang (sea cucumbers), and shark and other fish are harvested, but the effects on the reefs are unknown. All reefs have hard coralline algae pavements and low and stunted

corals in exposed high wave-energy areas, and high coral cover and a large variety of growth forms in sheltered habitats. The condition of the coral communities at all reefs was good through most of the 1990s. However Scott Reef was bathed in warm water and seriously bleached, with high coral mortality to depths of more than 30 m during 1998.

Cocos-Keeling and Christmas Islands

These are particularly isolated reefs in the Indian Ocean, much closer to Indonesia than Australia. The Cocos-Keeling Islands are atolls south of Sumatra at about 12°S and the Christmas Islands are a terrestrial park (due south of Java) which predominantly have fringing reefs. Population density on both groups is very low (600–700) and has a low impact on the reefs, except for some over-harvesting of some molluscs (Lambis lambis). The Cocos-Keeling Islands have been proposed as an Australian protected area. The reefs are in virtually pristine condition, but there were reports of two large-scale coral die-offs in the past, with significant recovery of the corals afterwards.

The Dampier Archipelago and Monte Bello Islands

These reefs and islands (21°S) are on inshore and mid-shelf parts of the continental shelf, respectively. There is high diversity and abundance of corals and fish, and despite increasing pearling, petroleum, fishing and tourism activity, there is no evidence of significant human damage to the reefs. The Monte Bellos were used for British Nuclear tests from 1952–1956.

Ningaloo Reef

The Ningaloo Marine Park extends from 22°S, southwards for about 230 km. There is a long fringing reef, separated from the shore by a 3 km wide sandy lagoon. All this is adjacent to a desert, which is unlike the eastern side of Australia. Coral and fish communities are diverse and abundant and fishing is only permitted in parts of the marine park. Outbreaks of a coral-eating snail (Drupella) killed much of the coral in some areas in the 1970s and 1990s, and other areas have been damaged by low oxygen conditions when coral spawn decomposes. Now, new corals are recruiting and restoration of coral cover is progressing, but many areas are still dominated by dead coral and rubble. A broad-scale monitoring program has recently been established.

Abrolhos Islands

The Abrolhos Islands and coral reefs (28°S) are the southern limit of reef development in western Australia. The reefs, which have extensive areas of both kelp and corals, are the site of a major and well-managed rock lobster industry worth AUD$13.5 million per year. The use of lobster traps is banned from areas with fragile corals, and there is no indication of any widespread detrimental effects on the coral and fish communities. These reefs are in

good to excellent condition and plans have been prepared for declaring the area as a marine protected area. There is extensive oil and gas potential in offshore areas, and this may be an important test case for the coexistence of an oil industry and productive coral reefs.

Other areas of Australia

There is coral growth on rocky reefs south of the Great Barrier Reef in southern Queensland Gneering Shoals (26°S), Flinders Reefs (27°S) and northern New South Wales (28°30'S) on rocky reefs with populations of corals up to 50% coral cover.

There are also large areas of sparse coral communities, but with low coral cover in northern Australia around Darwin. Many of these areas are dominated by soft corals and gorgonians. A major protected area is the Coburg Peninsula Marine Park and Sanctuary, which is managed by the Northern Territory Conservation Commission.

Management of Australian reefs

The reefs in Australia are well managed and are seen to be under no immediate threat of widespread degradation from use and impacts by local communities, although some scientists are concerned there could be long-term damage caused by aspects of global climate change. In 1975, the Australian and Queensland state governments set up legislation to manage the whole area of the GBR and established the Great Barrier Reef Marine Park Authority (GBRMPA) which has responsibility for the World Heritage listed GBR Marine Park. This was immediately after an active public campaign to stop oil drilling and mining on the GBR. The Act of Parliament listed the task of planning and managing the GBR as: 'to provide for the protection, wise use, understanding and enjoyment of the Great Barrier Reef in perpetuity through the care and development of the Marine Park'. The environment department of the State of Queensland has responsibility for day-to-day management of the GBR Marine Park, such as enforcing fishing regulations; while GBRMPA is responsible for policy and strategic management, including giving permission for tourism activities in the park and directing some research and monitoring. The primary methods of management are restriction of use in some places by creating zones and management plans, and regulating reef use through issuing permits. Mining and oil drilling are prohibited in all parts of the marine park. Commercial use of the marine park requires a permit, and must be consistent with zoning and management plans.

There are many reasons why managing the Great Barrier Reef (GBR) has been different to managing other areas:

- the GBR is a very large system (2000 km long) and most parts are closely connected by currents which supply fresh larvae;
- most reefs of the GBR are remote from land (more than 30 km offshore);
- population density on the nearby coast is very low;
- fishing and other exploitation is moderate and there is no subsistence fishing;
- the economic status of the local population is relatively high;
- the local people have a high conservation ethic and strongly support the need for management;
- there is strong support from all levels of government and there are adequate funds for effective management;
- there is a strong marine and social science community able to provide valuable data and support for management.

Management of the GBRMP has been facilitated through extensive consultation with local populations, farmers, fishing groups (both recreational and commercial), the tourist industry, NGOs and the indigenous communities along the coast. All these people are represented on a special advisory body (Consultative Committee), which provides direct advice to the senior committee (The Authority) which contains a representative of the Australian Government, the State Government of Queensland, a representative of the broader community and a representative of indigenous peoples.

A special feature of the GBRMP, compared to other types of protected areas (e.g. national parks), has the division of the area into seven different zones. The zones are designed to cater for all users and also to ensure that significant areas are conserved and protected. The major activities being controlled are fishing, collecting and tourism. The major direct human threat to the areas surrounding the reefs is fishing by trawlers. In 1981, it was proposed that at least 10% of the sandy bottoms would be closed to fishing, now the figure is 15% to 30%.

There are two zones for the sandy bottoms around the 2800 reefs:

- in 80% of the area (General Use Zone), trawl fishing is permitted;
- in the remaining 20% (Habitat Protection Zone and other categories), trawling is banned.

On the reefs, there are four zones:

- Habitat Protection Zone (76% of reefs) — all fishing is allowed, for example commercial and recreational fishing, including spearfishing, but trawling, some collection of animals and spearfishing with SCUBA are all banned;
- Conservation Park Zone (2% of reefs) — here commercial fishing, spearfishing and collection of animals are banned, while allowing recreational fishing;
- National Park Zone (21% of reefs) — accentuates protection of the reefs by only allowing tourism, but preventing all fishing and collecting. In some areas there is a Buffer Zone that allows for the catching of pelagic fish;
- Preservation Zone (1% of reefs) — this prevents entry by all people, except research under very strict conditions.

Tourism is allowed in all zones, except the Preservation Zone, however, operators can place floating tourist pontoons on about 60% of all reefs, usually only one structure being allowed on each reef. Currently about 16% of the reefs in the marine park are zoned to prevent any extractive activities. All zones are protected by legislation and are intended to remain unchanged for five years, after which they can be renegotiated and re-zoned for a similar period. GBRMPA has continuing government funding, which is now supplemented by a day fee of AUD$6 for all tourists visiting the reef.

Management of western Australian reefs is carried out by the Environment Protection Agency for environmental impact assessment, and by the Conservation and Land Management Department of the Western Australian state government, which is responsible for declaration and management of marine protected areas. The management status of the reefs and the capacity on the ground are good, but many proposed MPAs have not yet been implemented. There are important potential threats from oil industry activities, but no major degradation has been recorded so far.

Conclusions

The outlook for the reefs of Australia is very good. The appreciation of the reef resource and support for its management will increase as the population grows relatively slowly and economic conditions improve for the people. This will mean that greater resources will be put towards improving management and decreasing human pressures on the reefs, for example improving agriculture and grazing practices to reduce sediment and nutrient flows onto the GBR.

Also there is an increased appreciation of the value that coral reefs bring to the Australian economy, particularly in attracting international tourists. Reef management is backed up by very strong research capacity at the Australian Institute of Marine Science, at James Cook and other universities and in other arms of government. There are also strong social science and policy studies conducted by GBRMPA, government departments and universities.

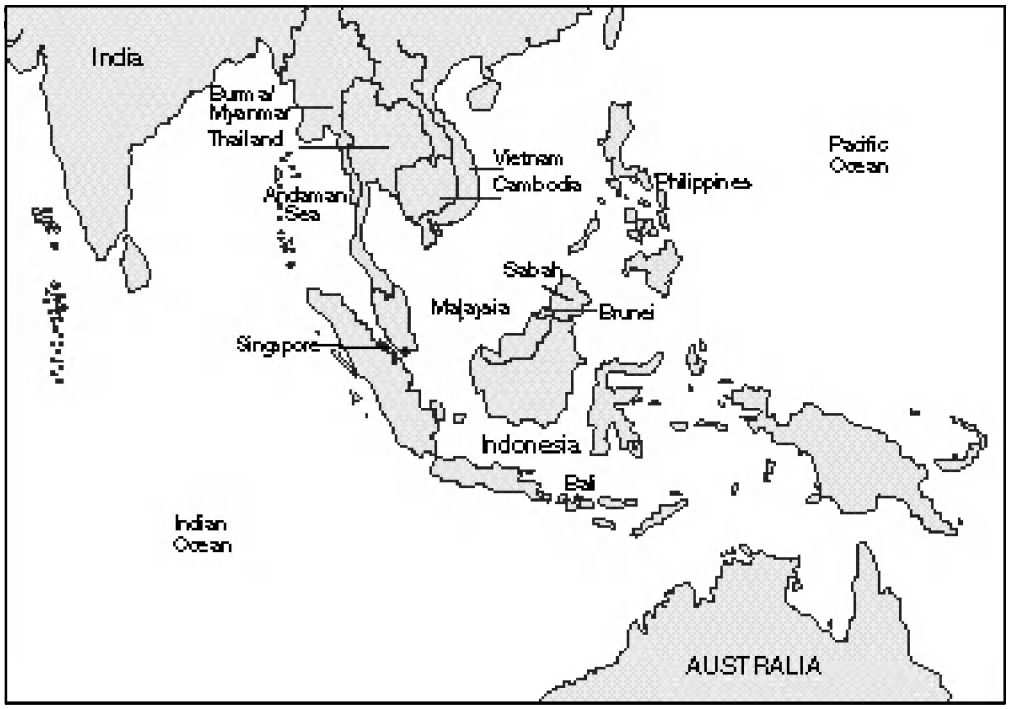
Terry Done leads two coral reef research groups, one at the Australian Institute of Marine Science and the other at the Reef Cooperative Research Centre, a body that brings tourism and other industries into research and management; Clive Wilkinson coordinates the Global Coral Reef Monitoring Network based at AIMS. We thank the following colleagues for comments and information: Jamie Oliver from GBRMPA; Hugh Sweatman and Andrew Heyward from AIMS; Vicki Harriott and Peter Harrison from the Southern Cross University; Chris Simpson from the Western Australian Department of Conservation and Land Management.

6. Status of southeast Asian coral reefs

Loke Ming Chou

Abstract

Southeast Asia has about 30% of the world's reefs and is the centre of biodiversity for hard corals and most other reef animals and plants. The region is also experiencing rapid population increases and dynamic economic growth, concentrated mainly in coastal areas. Heavy reliance on the marine resources has resulted in non-sustainable use and degradation of many coral reefs. Most reefs close to major populations have deteriorated drastically. Some remote reefs may remain in pristine condition, but there are increasing threats from roving bands of fishers taking fish by destructive means, especially cyanide. Pressures will increase as accessibility improves and the demand for fish, especially for the live fish trade, expands with economic wealth. Countering this is a demand from marine tourism for untouched reefs, which can generate long-term sustainable income if managed carefully.



Of 49 reefs monitored in five ASEAN countries, less than 20% had live coral cover in excess of 75%. Many of the reefs also showed a steady decline in live coral cover with time. In response, increasing numbers of marine protected areas are being gazetted throughout the region, but less than 10% maintain a high level of management. Awareness is expanding rapidly, but recent economic turmoil will mean that calls for conservation of reef resources may go unheard in the rush to return economies to growth.

INTRODUCTION

Southeast Asia occupies only 2.5% of the ocean surface, but contains 30% of the world's coral reefs, and links the Pacific and Indian Oceans. The reefs stretch across longitudes 93°E to 141°E and straddle the equator from 21°N to 11°S. There are over 25,000 islands, some just small dots, but there are also two of the world's largest archipelagoes, Indonesia with more than 17,000 islands, and the Philippines with over 7000 islands. All reef types are common, including oceanic atolls, barrier reefs, and platform reefs, and many of the islands have fringing reefs.

Everything is favourable for reef growth — the right geology, oceanography, and climate, and there are only tropical storms at the higher latitudes in the Philippines, Thailand, and Vietnam. Many of the reefs are on the large Sahul and Sunda continental shelves; others fringe old volcanoes arising from deep oceanic waters. The richness of coral species is the highest in the world, and this is also the case for fish, molluscs, crustaceans, and echinoderms.

Direct and indirect human pressures now pose the greatest threat to Southeast Asian reefs. The population of 450 million today is expected to almost double to 716 million by the year 2025. The majority of these people live along the coast, and development pressures have caused the loss of many reefs, particularly those close to large populations. Most reefs show significant damage from over-fishing, pollution and sediment damage. Scientists in the region ranked sediment loading (due to dredging, coastal development and engineering, and coral sand mining) as the most serious threat, followed by nutrient pollution from sewage and agriculture, oil pollution, and industrial pollution. The fastest growing source of damage to all reefs, particularly the remote ones, is through over-fishing with dynamite, muro-ami (driving fish into fixed nets by bashing the coral with rocks and poles), and cyanide. In addition, unregulated tourism, coral mining, and nearshore trawling, have caused considerable damage to the reefs. All human impacts were ranked higher than natural impacts.

Fish are the main source of animal protein in the region, with reef fisheries contributing up to 30% of the total catch. Major food fish from the reefs include grouper (serranids), snapper (lutjanids and lethrinids), rabbitfish (siganids), fusiliers (caesionids), and mackerel,

tuna, and carangids. Squid, cuttlefish, and molluscs are also taken from reefs. But there have been major declines in catches, indicating that many stocks have been depleted beyond sustainable levels. For example, reef fisheries in the Philippines once provided up to 36 tonnes per square kilometre each year, but the degraded reefs offer only 10–15% of this amount. In addition to food from the reefs, there is also a major curio trade in shells and corals, and in live animals for the aquarium trade, most of which are exported beyond the region.

This region has an excellent capacity to assess reef status and do reef research, which derives in part from the ASEAN-Australia Living Coastal Resources project in five ASEAN countries (Indonesia, Malaysia, the Philippines, Singapore, and Thailand) from 1984 to 1994. During this time, there were over 959 line-intercept survey transects, each 100 m long at 42 reef locations. The results showed that less than 3% of the reefs surveyed in Indonesia, Malaysia, and Singapore could be considered as 'Excellent', and assessments by experienced scientists suggested that there is a 70% increase in degraded reefs in the last 50 years, with productivity losses of up to 80%. Scientists reported a high diversity of fish species, with 307 species in the Philippines, 268 in East Indonesia, and 179 in West Indonesia. A lower diversity of species was found in East Malaysia (144), West Malaysia (118), Myanmar (86), Vietnam (83), Singapore (77), East Thailand (77), West Thailand (70), and Brunei Darussalam (38).

The strongest natural influence is the annual monsoon, which reverses current flows and introduces freshwater into coastal areas, lowering salinity and increasing sedimentation. Typhoons affect the Philippines, Vietnam, and Thailand, while volcanic and tectonic activity occurs in Indonesia and the Philippines. Isolated instances of Acanthaster plagues have occurred. Widespread coral bleaching occurred over many of the region's reefs in the early half of 1998. This was triggered by elevated sea-surface temperatures connected to the El Niño phenomena.

Status of reefs

Brunei Darussalam

The few coral reefs are offshore, because coastal areas are dominated by sediment-laden rivers. Coral cover is generally low for this region, with 40% at Pelong Rocks, and 27% at Two Fathom Rock. Brunei lays claim to part of the Spratly complex of reefs — Louisa Reef, 230 km off the coast. An initial study showed there were 88 coral species belonging to 52 genera.

Burma/Myanmar

Most of the reefs are in the southeast around the numerous islands of the Mergui Archipelago. The reefs have 65 coral species in 31 genera, but this may be an underestimate as few studies

have been conducted. There are few natural stresses to these reefs, but human factors are known to be very high.

Cambodia

Very little is known of the few reefs around the offshore islands near Sihanoukville because of the lack of capacity, and persistent political turmoil in this region.

Indonesia

Fringing and patch reefs are common around most islands of the Indonesian Archipelago. Barrier reefs grow well along the edge of the Sunda shelf, east of Kalimantan, and around the Togian Islands of central Sulawesi, and in the deeper seas to the east. Taka Bone Rata, in the Flores Sea, is the third largest atoll in the world. Pulau Pulau Seribu, or Thousand Islands, form a spectacular chain of platform reefs with many coral islands out from the capital Jakarta. The count of 359 coral species from eastern Indonesia is an underestimate, as many new species have been discovered recently.

Tropical storms have little impact on Indonesian reefs, but rough seas and freshwater runoff from the two reversing monsoons each year do control reef growth in some areas. The 1983 El Niño event raised sea temperatures in the Java Sea and caused up to 90% coral mortality on the reef flats of many of the Seribu Islands. Five years later only half of the coral had recovered. Acanthaster damage has caused severe damage to some reefs, including the Seribu Islands, but no recent population outbreaks are known.

Reefs in western Indonesia are subject to greater human pressures than reefs in the east. For example, coral cover on almost 40% of the reefs in the Seribu Islands is 'Poor', and only 5% have 'Excellent' coral cover. There is considerable sediment and nutrient pollution coming out of the city of Jakarta, and from the many small tourist resorts on the islands. Subsistence fishing pressures are very high and fish catches have declined with loss of coral cover, for example catches decreased from 1350 tonnes in 1973 to 100 tonnes in 1990. In eastern Indonesia, 22% of the reefs were 'Poor', and 7% were 'Excellent'. All reefs near centres of population suffer from human impacts, and now there are many roving bands of fishermen who are damaging remote reefs by fishing using dynamite, cyanide, and muro-ami methods. Indonesia has started a massive Coral Reef Rehabilitation and Management Project (COREMAP) aimed at safeguarding the country's dwindling coral reefs, and slowing degradation. An economic analysis showed that the value of intact coral reefs to the Indonesian economy in tourism and sustainable fisheries was 50 times greater than the value obtained by using cyanide to collect fish, and mining coral rock and sand.

Malaysia

Most of the coral occurs as fringing reefs along the coast or around the offshore islands on the east coast of peninsular Malaysia with 55–70% coral cover on most reefs. Whereas there is much less growth on the west coast, with 25–45% cover, due to the higher concentrations of sediment. Fringing reefs are found on the coast of Sabah in East Malaysia, with much more around offshore islands, where there are also patch reefs. Live coral cover is between 43% and 52% with more dead coral and rubble than peninsular Malaysia, due to the common practice of blast fishing. The waters around Sarawak are muddy and contain a few poorly developed coral communities, but often have 60% live coral cover. The only true atoll is Layang-Layang in the Spratlys, where clear waters permit coral growth to a depth of more than 40 m, but cover on the upper slopes was naturally low at 29% because of oceanic waves. The recent development of a resort and airstrip caused a massive 75% loss of live coral cover. Over 350 coral species are found on Malaysian reefs, with Acropora the dominant genus.

Extreme low tides have killed corals on the east coast of the peninsula, while sporadic Acanthaster outbreaks have damaged most reefs, except those on the west coast of the peninsula. On these west coast reefs, there are seasonal blooms of macroalgae, because the large amount of development has caused much sediment and nutrient pollution. Fishing pressures are very high in east Malaysia, and there is regular use of blast and cyanide fishing techniques. The government has declared a number of islands as MPAs and this is having a beneficial effect to conserve corals and fish.

Philippines

Most of the reefs, which cover an estimated 25,000 km^2, are fringing reefs and vary in length from tens of metres to 5 km. The largest concentration is in the southwest. The best of the Philippine reefs are the two atolls in the Sulu Sea (Cagayancillo and Tubbataha), the atoll-like formations (like Apo Reef near Mindoro Island and Scarborough reefs west of Luzon), and the banks west of Palawan (one of the largest barrier reef areas in the world). A double-barrier reef grows on the Danajon Bank off Bohol, and a few more small barrier reefs are also present. There have been 499 species of hard corals reported from the Philippines. Surveys showed that only 3.6% of the reefs in Luzon were in 'Excellent' condition, while 27% had less than 25% coral cover. In the Visayas near the middle, 6.6% were in 'Excellent' condition, while 31% were 'Poor'; and in the far south in Mindanao, 5.3% were in 'Excellent' condition and 49% 'Poor'. Recent surveys show that there may be some recovery as there is a greater proportion of live coral cover compared to dead coral.

Typhoons cause extensive damage to northern reefs, such as at Mactan, while Drupella and Acanthaster infestations have caused significant local damage. The eruption of Mt. Pinatubo in

1990 resulted in massive flows of ash onto reefs of western Luzon. This caused a 23% to 69% decline in fish biomass on reefs along the coast of Zambales, along with a drop in live coral cover. Human impacts are, however, far more damaging. More than 80% of Philippine tropical forests and mangroves have been cleared, resulting in massive amounts of sediment flowing onto the reefs. There is virtually no treatment of domestic and industrial wastes, which mostly flow into the sea. Over-fishing has caused considerable damage to all reefs, both coastal and offshore. Because of the high level of poverty and large numbers of fishermen, most reefs have been stripped of fish that are easy to catch with lines, traps and nets. Now fish are being caught using destructive methods like muro-ami, home-made bombs, and cyanide. The rich trade in live fish for restaurants in Hong Kong has meant that large reef fish are virtually extinct on most Philippine reefs, with fishermen able to take fish from as deep as 40 m using compressed air.

Giant clams were once abundant but were virtually wiped out from many reefs through over-fishing. Brood stocks were imported for clam hatcheries in Bolinao and Dumaguete, and juvenile clams are being used to restock Philippine reefs, and provide an income for local fishers. The Philippines is one of the largest exporters of live and dead coral, and other species such as anemones, for the aquarium trade. This has also contributed to the decline in Philippine reefs.

The Philippine government has been active in encouraging local level management of coral reefs, and there are a few outstanding examples of success. The best known is Apo island off southern Negros, and many other examples of management of reef resources are developing around the country. Successful national parks have been established for the Tubbataha reefs in the Sulu Sea and the El Nido reefs of west Palawan, however, over-fishing at El Nido is causing damage to these tourist reefs.

Singapore

All of the reefs are around the southern offshore islands, where more than 197 hard coral species in 55 genera are known. The area is relatively sheltered and on the equator, therefore damage from tropical storms is negligible. No Acanthaster have been recorded. However, about 70% of Singapore reefs are now degraded compared to the pristine condition 50 years ago. Recent data indicate a further decline in live coral cover on the upper slope of the better reefs (76% in 1989 to 69% in 1993). The major cause of reef degradation is sedimentation brought about by four decades of land reclamation, dredging of navigational channels, and dumping of dredged materials further out to sea. Reef slopes below the depth of 6 m support little live coral cover compared to the early 1960s when water was clearer and coral growth extended to 10 m. Many of the reef conservation measures are initiated by nongovernmental organisations (NGOs), and increased awareness has brought about the creation of a 'marine nature area' by the government in 1996. This area encompasses six islands, all with fringing reefs.

Thailand

There are over 300 major reef groups covering an estimated area of 12,000 km^2 divided into four areas: i) inner part of the Gulf of Thailand (Chonburi); ii) east side of the Gulf (Rayong and Trad); iii) west side of the Gulf (Prachuap Kirikhan, Chumporn, and Surathani); and iv) along the Andaman Sea coastline (Ranong, Phuket, Phang-Nga, Krabi, Trang, and Satun), where about 55% of Thailand's reefs occur. The best reefs are in the provinces of Trad, Phang-Nga, and Trang, and the majority are fringing reefs, though there are many coral communities growing on rock as well. Over 60% of all major reef groups in Thailand have less than 50% live coral cover and there is increased algal growth because of nutrient pollution from the land, including near the major tourist resorts of Pattaya Bay, Phuket, and Ko Samui.

Storms and monsoon waves are the major natural causes of coral reef damage. Typhoon Gay hit southern Thailand in 1989 and caused major damage to some reefs. Localised outbreaks of Acanthaster have been reported in the Gulf of Thailand, and an increase in infestations has occurred in the Andaman Sea since 1982. Extreme low tides and coral bleaching are other natural phenomena causing severe damage. Like all countries of the region, sediment and nutrient pollution from development on the land is causing major damage to the reefs, along with significant over-fishing. Thailand has many large trawlers, which are now fishing close to reefs, causing damage. Much of Thailand's mangrove forests have been cleared for prawn ponds and timber, such that the natural sediment traps have been removed.

There is an active NGO network in Thailand, which is assisting communities with local management of coral reefs, and restoration of forests and mangroves.

Vietnam

Reefs that cover 400 km^2 occur along the 3200 km coastline of Vietnam, mostly around 3000 islands on the shelf and offshore. There are no reefs around the deltas of the Red and Mekong Rivers. There are five sub-regions with more than 300 hard coral species, but not all areas have been surveyed: i) reefs to the west of Tongkin Bay and Gulf have coral cover from 30% to 50% with 165 coral species; ii) central Vietnam; iii) in southeast Vietnam there are 176 species including the Con Son Islands off the southern tip, which are particularly rich in species; iv) west of south Vietnam (Gulf of Thailand) there is between 30% and 40% cover and 138 species; and v) the offshore islands and atolls in parts of the Spratlys claimed by Vietnam, have the highest coral diversity (188 species).

Storms and typhoons, and low winter temperatures are the major natural stresses, and sediment runoff and pollution because of rapid economic development, are causing

damage to the inshore reefs. The offshore reefs are being damaged by fishing activities including trawling, the use of dynamite and cyanide, and over-fishing. Vietnam commenced its Marine Conservation Project in 1992 aimed at managing marine resources, including coral reefs.

Status of ASEAN coral reefs

In most areas, live coral cover should be high (>50%) because there are few tropical storms, so the major factors determining coral cover are human disturbance. Data are from the ASEAN-Australia Living Coastal Resources project on transects usually at 3 m and 10 m depths on the reef slope. Condition values refer to percentage of transects with coral cover of Excellent >75%; Good <75->50%; Fair <50->25%; and Poor <25%.

Country	No. of transects	Excellent %	Good %	Fair %	Poor %
Indonesia	190	2.6	24.2	31.6	41.6
Malaysia	193	11.4	52.8	27.5	8.3
Philippines	238	1.3	7.5	49.2	42.0
Singapore	142	2.8	9.2	20.4	67.6
Thailand	178	16.9	42.1	34.8	6.2

Coral Reef Management

Many reef management systems exist in the region and numerous marine protected areas (MPAs) have been established in Southeast Asia. But many of these exist only on paper with no staff or operational funding. About 10% of the 106 MPAs established in the ASEAN countries are effectively managed, and few staff are adequately trained in park management and lack the enforcement resources to control damaging activities. There is poor coordination and communication between agencies managing different parts of the coast, and resulting conflicts are undermining conservation and protection efforts. There is a need for increased political commitment to conserve Southeast Asia's coral reef resources.

Community-based management is achieving better success using a range of different models, particularly in the Philippines and Thailand. Community management of local areas provides better motivation to manage the resources that communities depend on, and results in effective control of destructive activities. Co-management between government agencies, local communities, and NGOs is more effective for larger areas.

Many Southeast Asian countries have signed international conventions and agreements like the Convention on Biological Diversity, and the Convention on International Trade in Endangered Species (CITES). These have been effective in slowing the export of live and dead corals from the region. A number of informal agreements, such as the 1989 Langkawi Declaration on the Environment, the 1990 Baguio Resolution on Coastal Resource Management, the 1990 Kuala Lumpur Accord on Environment and Development, and the 1994 Bangkok Resolutions on Living Coastal Resources, demonstrate increased awareness about managing coral reefs for sustainable use.

The future

Southeast Asian reefs have been heavily exploited during in the last 30 years, with economic growth and population increases causing the collapse of about 11% of the reefs. A further 48% are in the critical category, with collapse likely within the next 20 years, if management commitments are not met. Policy makers now know that managed reefs provide sustained benefits, but government bureaucracy and inter-agency conflicts prevent effective management beyond the declaration of MPAs. The best way to conserve coral reefs is through integrated coastal management, but Southeast Asian countries are still a long way from adopting national conservation policies. Short-term development overrides the need for sustainable development and adherence to international agreements.

Implementing an action agenda to conserve these high biodiversity reefs is urgent, and the agenda must gain full support from all sectors of government, users, and the public. Effective coral reef conservation requires that local users and officials are informed and involved in sustainable resource management, backed up by excellent legislation, planning, and enforcement by governments. The current rate of reef degradation can only be reduced when there is better understanding of reef functions and the need for MPAs. If human pressures can be reduced, reefs in oceanic waters should recover rapidly, because there is a ready supply of larvae and clean water, but reefs on the continental shelves close to polluted areas will not recover fully until the pollution buried in the sediments is washed out.

Professor Loke Ming Chou is from the Department of Biological Sciences of the National University of Singapore.

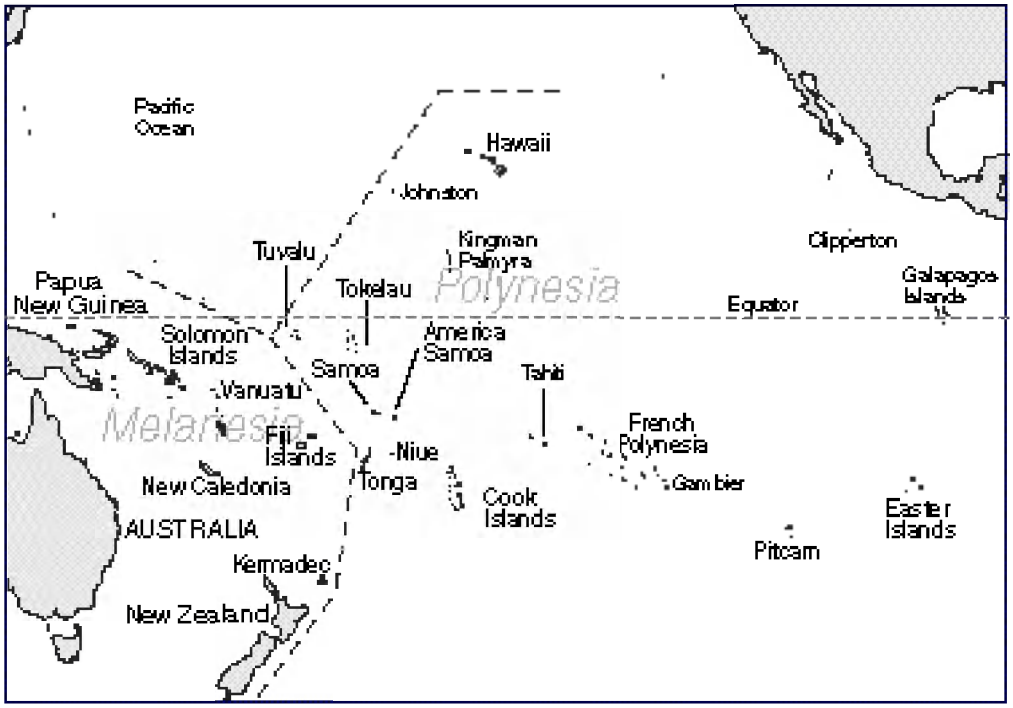
7A. Status of coral reefs of the southwest and east Pacific: Melanesia and Polynesia

Jim Maragos

Abstract

The tropical southwest and east Pacific covers a vast area with 18 governments or territories scattered over thousands of islands. The largest islands in the tropical Pacific occur in some of the countries, and many others have only small amounts of land resources. The subsistence cultures in most of the islands are heavily dependent on the sea and coral reefs for protein foods, sand and rock for building, and on protection from oceanic waves and storms.

The majority of Pacific coral reefs remain in good to excellent condition, with only those reefs near large urban areas being chronically degraded. But it is these reefs that are often most important for subsistence fishing, recreation and tourism, shoreline protection, and other benefits. Fortunately, about 99% of all reefs occur outside the influence of urban pollution and degradation.



The largest threats to these reefs arise from rapidly increasing populations on these islands and in countries surrounding the region. Where these populations are concentrated, there is significant over-fishing, particularly of resources like giant clams, sea cucumbers and trochus shells. An increasing trend on the remote reefs, is roving bands of fishermen who systematically remove these resources, and use cyanide and dynamite to remove fish for the insatiable markets of Asia. Recent surveys have shown that sharks and lobsters have been removed from even the most remote reefs.

The other major threat to some countries is rising sea levels as a result of global climate change and the possibility of more frequent and stronger El Niño events. Islands that are subsiding rapidly are susceptible to relative sea level rise, and particularly those formed on coral reef atolls where just a half a metre rise will result in sea water penetrating into the fresh water lens under these sandy islands. This will prevent agriculture and remove dry season water supplies, and mean that island cultures will have to be relocated to unfamiliar lands.

INTRODUCTION

The Pacific has four regions: Melanesia (5,500,000 km^2) in the southwest Pacific; and Polynesia (13,200,000 km^2) in the eastern Pacific are discussed below. Micronesia (8,800,000 km^2) in the central and northwest Pacific; and the reefs of east Asia are in the companion review (Ch. 7B). There are five types of island and reef systems within the Pacific:

- fringing reefs including channels and holes around either volcanic or coral islands;
- barrier reefs, including passes and lagoon reefs off high islands;
- atolls including one or more low coral islands generally surrounding lagoon and associated reefs;
- submerged reefs which are subtidal and often associated with deeper terraces and shelves off larger continental-like islands; and
- reef communities where true structural coral reefs are absent, due to less than optimal conditions, or are growing on recently formed rocks, for example volcanoes.

This review covers **Melanesia,** south of the Equator and in the west of the Pacific, and **Polynesia** covering virtually all that area to the east of the International Date Line. Melanesia was settled between 13,000 and 40,000 years ago, whereas Polynesia was settled more recently, beginning about 5000 years ago.

Status of reefs in the Pacific

Most coral reefs in the Pacific are in good to excellent condition, with those near many urban areas being chronically degraded. Although 99% of reefs are removed from the immediate influence of urban pollution and degradation, many remote reefs are subject to illegal and often destructive fishing. Low live coral cover is not necessarily a sign of unhealthy reefs, as few Pacific reefs have 50% or more coral cover. Because of high wave exposure and tropical storms, reef-fronts and shallow reef flats may be just bare pavements dominated by coralline algae. Most reefs in the Pacific can recover rapidly from major stresses, as they are usually surrounded by deep, clean water, which provides coral reef larvae. Lagoons with limited water exchange with the outside often recover slowly from stress, such as crown-of-thorns starfish predation or pollution.

Coral reefs near the few urban areas are being chronically degraded, and these are the most important reefs for subsistence, recreation, protection from natural hazards, tourism, and other benefits. Reefs near rural or uninhabited islands experience lower levels of pollution, physical modification, and ecological stress. Human populations are increasing rapidly on many Pacific islands and there are high levels of migration to urban centres. Some countries are resettling communities to sparsely inhabited or uninhabited atolls and islands to relieve pressure on the large towns. Without effective population control programs, more reefs will become degraded or polluted. In addition, the massive population increases in Asia and the Americas are increasing the commercial demand for fisheries products, leading to more reef degradation, particularly on isolated and remote reefs beyond the watchful eyes of local residents. However, the bulk of reefs in this part of the Pacific do not face immediate threats.

Natural stresses to southwest and east Pacific reefs

Stresses to reefs can be either intermittent, or chronic and mild, or severe. An example of severe stress is low average and low winter sea-surface temperatures that restrict coral reef growth in the eastern Pacific and in subtropical latitudes such as in Kermadecs. Large waves arising from polar storm fronts can be particularly damaging to island chains in the Pacific, for example Hawaii, which is exposed from virtually all directions. Many islands, such as Hawaii and Samoa, are relatively new and rapidly subsiding, while others like Vanuatu and the Solomons are older and rapidly emerging. Both processes disrupt reef growth. Earthquakes and volcanic eruptions are common and can bury or damage reefs in many Pacific islands, for example Papua New Guinea, and Vanuatu. Tropical cyclones probably damage more reefs in the Pacific than any other natural stress. Where they are frequent, such

as in French Polynesia, or Vanuatu, the reefs are more compact and have low coral cover. Bays, reef lagoons and reefs near river mouths off large islands, such as southwest New Guinea, Samoa, Hawaii, Fiji, and Tonga, are often impacted by massive freshwater flows that kill corals not tolerant of lower salinities, and also prevent re-settlement on the soft sediment bottoms. The El Niño southern oscillation generates warm water around the equator in the east Pacific, which can drift westward through southern Polynesia, sometimes as far west as Melanesia, and may cause temperature extremes and extensive bleaching and death to corals. Another El Niño impact can be sea level extremes, including local lowering of sea level by nearly a metre. When this coincides with spring low tides, corals on reef flats can be killed after being exposed to the air for several hours. Crown-of-thorns starfish (Acanthaster) outbreaks have periodically caused massive losses in coral cover on many reefs, for example Fiji and French Polynesia. There have been few reported instances of coral disease, for example coralline lethal orange disease was observed in the Cooks and Fiji. However, large areas of the Pacific have not been examined.

Human stresses to Pacific reefs

Human damage to coral reefs includes sewage and sediment discharges off high islands with larger populations, particularly the volcanic islands, for example southeast New Caledonia, Papua New Guinea, Hawaii, Society Islands, Fiji, Solomons, and also on some raised coral islands (e.g. Tongatapu). There are also many other human impacts on coral reefs, for example coastal construction, solid waste disposal, former military sites, over-fishing, mining/industrial pollution, which generally decrease rapidly away from the centres of population. Unstressed reefs recover much better from episodic, natural stresses like lava flows, earthquakes, bleaching, tropical cyclones, lower sea level, and Acanthaster, because oceanic water in most of the Pacific is virtually pristine. A combination of chronic human stresses and natural stresses, for example lower temperatures, subsidence, and exposure to heavy wave action, may permanently degrade reefs, especially near urban centers.

The increase in destructive fishing that largely emanates from Asia is also impacting on some parts of Melanesia and Polynesia. Blast and poison (cyanide, bleach) fishing is increasing as good prices for fisheries products in Asia have encouraged locals to enter the export trade, often abandoning traditional management regimes. The introduction of dive masks, fins, and in some places SCUBA gear has facilitated the near extinction of giant clams, sea cucumbers, and trochus off many Pacific reefs. Giant clams are now being bred in the Solomons and re-introduced to many other Pacific reefs. Shark fishing has been conducted on virtually all reefs of the Pacific, including the most remote ones. Around tourist destinations, there has been damage to reefs from boat anchoring, snorkelling, or reef

walking, for example Hawaii, French Polynesia and Fiji. The introduction of alien species has the potential to cause impacts to reefs. Many introductions for mariculture are deliberate (seaweeds, oysters, sponges) or to enhance local fisheries (trochus, green snail, fish). In Hawaii, alien mangroves and algae now monopolise inshore reef flats on several islands, and have displaced corals and other reef life. There are occasional threats from ship groundings and oil spills.

MELANESIAN COUNTRIES

These five countries (Fiji, New Caledonia, Papua New Guinea, Solomons, Vanuatu) in the southwest tropical Pacific are mostly large, volcanic islands that were formed relatively recently by tectonic plate movement, earthquakes, and considerable submergence and emergence. Tropical cyclones are also common at higher latitudes (more than 7°S). Barrier reef systems are numerous (at least 36) including the world's second largest barrier reef, surrounding Grande Terre in New Caledonia. Fringing reefs are numerous but generally narrow, due to steady emergence, and submerged reefs are also abundant on continental shelf-like features off larger islands, especially in the Solomons. Melanesia has the highest density of large islands and the most complex reefs in the Pacific. There is the highest biodiversity of corals, fish, seagrasses, mangroves and other reef species, for example there are well over 300 species of stony corals. The species diversity of corals in Papua New Guinea is among the highest, with a slight decrease going south to Vanuatu and New Caledonia, and east to the Solomons, and Fiji, but few recent studies have been made.

Fiji

Most reefs are in good condition with little pollution and low fishing pressures. However, around the major cities of Suva and Nadi, there is clear evidence of damage to the reefs from development, upland mining, pollution, logging, coastal construction, and over-exploitation. Sedimentation and flooding are also major concerns for reefs near Suva, off the wet southeast coast, and tourism development off the west coast of Viti Levu is concentrated and expanding. Some reef resources, such as giant clams and sea cucumbers, were virtually wiped out after free- and scuba-diving equipment was introduced. In most traditional societies on the outer islands, the village chiefs maintain traditional management practices to conserve reef resources. There is increasing concern that destructive fishing practices, like blast and cyanide fishing, will increase on the remote reefs. The University of the South Pacific in Suva has a good capacity to monitor and research coral reefs. However, no reefs have yet been declared as marine protected areas.

New Caledonia

This is a department of France, which is now considering independence. The second largest barrier reef in the Pacific encircles the main island, Grand Terre, which is the third largest island in the Pacific. There are also small volcanic, and uplifted coral islands, and some atolls. The reefs are generally in good condition, with cyclones as the major natural stress. The lagoon waters around the capital Noumea have been polluted by urban and nickel mining wastes. There are also increased sediment flows into the lagoon and onto the barrier reef from mining, forestry, land clearing, and agriculture. Population pressures are low, but there has been some over-fishing, poorly planned coastal development, and clearing of mangroves. The Universite Francaise du Pacifique, ORSTOM, IFREMER, the Noumea Aquarium, and the South Pacific Commission all support research facilities near Noumea. Four reefs have been declared as protected areas (Table 1, page 104).

Papua New Guinea (PNG)

Papua New Guinea consists of the western end of the large island of New Guinea, along with thousands of other large and small islands, plus at least 40 atolls. The barrier, patch, and fringing reefs have particularly high biodiversity, but little is known. The southern reefs are exposed to cyclones, whereas those on the north are in an area of high volcanic activity, with frequent earthquakes. The large island has extremely high rainfall, and has the largest natural outflow of sediment to the ocean. The north coast is adjacent to deep water, so sediment does not remain, whereas the southern coast, especially the Gulf of Papua is shallow and muddy. There is distinct urban pollution of reefs off Port Moresby, but elsewhere sediment from logging and mining pose the greatest threat. Most reefs are in remote, sparsely populated areas with minimal disturbance and often have strong traditional management. The University of Papua New Guinea in Port Moresby is the chief research and education centre, but two other marine stations have recently closed. At least six marine protected areas have been established (Table 1).

Solomon Islands

These reefs are probably the least disturbed in the Pacific. The mostly volcanic and raised limestone islands have the second largest land area in the Pacific, with a very low (but rapidly growing) population. Reefs are predominantly fringing on the steep slopes of the volcanic islands, and most are in good to excellent condition. Although it has not been confirmed, the Solomons probably have the second highest biodiversity of Pacific reef life after Papua New Guinea. Volcanic activity, uplifting from plate tectonics, and tropical cyclones are the chief natural stresses, as well as sediment from large rivers. The reefs were heavily damaged during the war 50 years ago, but have almost totally recovered. Now the reefs are being impacted by sediment runoff from extensive upland logging and mining. Commercial and perhaps

destructive fishing may also be depleting some subsistence fishery stocks. There is some urban pollution immediately around Honiara, the largest town on Guadacanal Island. The ICLARM mariculture facility, and the Forum Fisheries Agency are the chief scientific centres on Honiara. Only one reef is protected (Arnavon), although many others would be suitable (Table 1).

Vanuatu

This is the smallest Melanesian country, but has the sixth largest land area in the Pacific. The reefs are mostly fringing, because the islands are relatively new. Natural stresses include cyclones, tectonic uplifting, tropical earthquakes, volcanoes, all of which control reef development. Species diversity is lower than in other Melanesian countries, but still high. Human stresses to the reefs include soil erosion and sedimentation from agriculture, cattle grazing, tropical forest logging, and urban pollution near the capital of Port Vila on Efate Island. Two reef areas are protected, and several others are proposed for protection (Table 1), but there are no research or higher education facilities.

POLYNESIAN COUNTRIES

There are 13 governments in this eastern half of Oceania, with more than 113 atolls, 84 fringing reefs, 21 barrier reefs, and 77 reef communities. Virtually all islands started as volcanoes, and there are still large volcanic islands with fringing reefs or barrier reefs in Hawaii, Samoa, and Societies (F.P). There are smaller volcanic islands and reefs in all other countries, except Tuvalu and Tokelau, which consist only of low-lying coral islands. Coral species diversity decreases sharply from west to east with nearly 300 species in Samoa and only a few species in the Galapagos in the far east. This is because most equatorial currents flow from east to west, which reduces the amount of larvae arriving from more biodiverse reefs to the west. However, there are more endemic species (up to 25%) in the east, especially in Hawaii and the Marquesas. Tropical cyclones and crown-of-thorns starfish (Acanthaster) outbreaks are the major natural disturbances to coral reefs throughout Polynesia, with more storms during strong El Niño years such as in 1982–1983. When storms are infrequent, such as in parts of Hawaii and French Polynesia, cyclone damage to coral reefs can be severe because the coral is dominated by fragile forms. Poor reef development in Samoa, Hawaii, and French Polynesia is due to a combination of rapid island subsidence, high wave exposure, strong trade winds, and lower seawater temperatures. Coral bleaching is often widespread in the southeast Pacific during El Niño years.

Cook Islands

The 15 islands are in two clusters: atolls to the north; and volcanic islands with some atolls in the south. These are in the southeast Pacific, just to the west of the Society Islands of

French Polynesia. Tropical cyclones are the most serious natural stress. The reefs and beaches of the high volcanic island of Rarotonga, the capital, have been damaged by urban development, soil erosion, and construction of a port, airfield, and hotels. Tourism and pearl shell culture (on northern atolls) are the main economic activities and there are two marine protected areas, although Suwarrow Atoll, may now be turned into a large commercial pearl shell farm (Table 1).

Easter Island (Rapa Nui) and Sala Y Gomez

Under Chile's jurisdiction, these two islands are at the far eastern end of Polynesia. There are no reefs and few corals on these old uplifted reefs. Tourism is growing rapidly on Easter Island, which may be a potential threat to the few corals. Both islands are now protected areas, but this does not extend to the marine resources (Table 1).

French Polynesia

The marine area of French Polynesia is the largest in Oceania, with more atolls and barrier reefs than any other area. The five major island groups are: Societies to the west (mostly volcanic islands with the most barrier reefs); Australs to the far southwest (mostly volcanic, with poor reef development); Gambiers (with mixed reef and island types) to the south-east; Tuamotus (all atolls except for one raised limestone island, Makatea) in the center; and the Marquesas (all volcanic) in the far northeast. Clipperton (the most easterly atoll in the Pacific) extends the territory of France to near Central America. Tahiti, the largest island in the Societies and French Polynesia, is the capital, and there are rapidly growing populations on Bora Bora, Moorea, Huahine, and Raiatea. Coral bleaching has killed 20–50% of coral cover in the last 20 years, and extremely low tides kill coral on reef flats. Cyclones are not common, but when they occur during strong El Niño years like 1982–1983, damage can be severe. Outbreaks of crown-of-thorn starfish have been devastating.

Major human impacts arise from soil erosion and sewage pollution, such as in Tahiti lagoon and other population centres. Coastal development and shoreline modification for urban and tourism development has changed water flows and caused damage to the reefs. There is heavy fishing pressure on some reefs, including large fish corrals in the passes to atoll lagoons, which remove virtually all species. Atmospheric and underground nuclear testing at Mururoa and Fangataufa atolls ended in 1996, with reef damage from both the blasts and installations. Pearl shell mariculture in many of the atoll lagoons, and tourism in the Society Islands are the main economic activities. At least seven marine protected areas have been established with major research and teaching facilities on Tahiti (Universite Francaise du Pacifique, ORSTOM and IFREMER) and on Moorea (CRIOBE centre of EPHE, and Gump Centre of the University of California, Berkeley). Specialist

mariculture centres (EVAAN) have been established on Tahiti and in the Tuamotus at Rangiroa Atoll.

Galapagos

These famous islands, in predominantly cold upwelling water, are administered by Equador. There are no true reefs, but large areas of coral with very low species diversity (about 20 species). Virtually all the coral cover was killed during a large bleaching event in 1982–1983. Fishing pressures have increased dramatically in the past 10 years for the export trade in sea cucumbers, shark, and fish. There are two large marine protected areas (Table 1).

Hawaii, US Line and Phoenix Islands

The USA has jurisdiction over the state of Hawaii, some of the nearby Line Islands (Johnston Atoll, Palmyra Atoll, Kingman Reef, and Jarvis Island), two of the Phoenix Islands (Howland and Baker Islands), plus American Samoa (page 99). The Hawaiian archipelago straddles the Tropic of Cancer in cooler tropical and subtropical waters, and is the longest and most isolated in the Pacific. The main volcanic islands are the largest in Polynesia with a population second only to Papua New Guinea. To the northwest, there are a chain of atolls and small islets on old volcanoes. There are fringing reefs on the large islands, and two barrier reefs off northeast O'ahu (Kane'ohe Bay) and north Kaua'i (Mana Reef). Coral and fish species diversity is lower compared to other reefs, but as many as 25% are endemic species (the highest in the Pacific). Natural stresses to reefs are also significant including large waves, hurricanes, earthquakes, lava flows, and low winter temperatures. There are large urban centres on the main islands including much of O'ahu (Honolulu), Maui, Kaua'i, Kona, and Hilo. Hawaiian reefs have always been exposed to soil erosion and flooding because the land masses are relatively recent. During the past century sugar cane and pineapple agriculture, ranching, and game preserves greatly accelerated soil erosion. Now, increased coastal construction for transportation, military bases, shore protection, housing and resorts, and sewage discharges from several outfalls, have increased sediment and nutrient impacts on the reefs. Most sewage and construction impacts have been controlled, but excessive fishing pressure, sedimentation, flooding, non-point source pollution, and invasive species continue to cause damage.

Howland, Baker, and Jarvis are uninhabited National Wildlife Refuges (NWR), and are fully protected by the US Fish and Wildlife Service. The only human impacts were from the use of the islands as temporary military bases during World War II. Johnston is both a NWR, and is used for incineration of chemical munitions and as a refuelling site for air travel. Extensive dredging and filling in the 1960s to expand the base caused considerable destruction to reefs, which have since recovered. Current impacts include disturbance from sport diving

and fishing, and discharge of sewage. The military sponsors marine research at Johnston. The Navy recently left Midway Atoll at the northwest end of Hawaii, and it is now another NWS complex, the last of the northwest or leeward Hawaiian islands and reefs to be placed in protected status. Kingman and Palmyra are uninhabited, and there are plans to designate Palmyra as another NWR. Military construction damaged many reefs of Palmyra during the war, but only some of the reefs have recovered.

Hawaii has the most marine protected areas (about 60) in Oceania (Table 1). Hawaii also supports many research institutions and higher education facilities, including state-wide campuses and laboratories of the University of Hawaii (including the Hawaii Institute of Marine Biology), Bishop Museum, several national and state fisheries laboratories, East-West Center, community colleges, Hawaii Pacific University etc. Several nongovernment and community organizations are also active in research, monitoring, and conservation of coral reefs. The national government recently passed an executive order protecting coral reefs, and other state and federal agencies are more active in reef conservation and monitoring.

Kermadecs

New Zealand extends jurisdiction over this cluster of volcanic islands south of Tonga in the subtropical southwest Pacific. There is a restricted coral and fish fauna, but no true reefs. Little is known of the marine resources, but there are probably endemic species. Low temperatures, volcanoes, large waves, and infestations of the crown-of-thorns starfish are the major natural stresses. There is some fishing pressure and the area is popular for sport divers.

Niue

This small raised coral island between Tonga and the Cooks, is a self-governing territory of New Zealand. Despite having over 40 coral genera, there are no true reefs or a lagoon. Coral communities grow as a veneer on the steep ocean-facing slopes and terraces around the island. The population of approximately 3000 Polynesians follows a traditional subsistence lifestyle, although tourism is increasing. There is some increased sedimentation and over-harvesting of food fish, but scientific information is limited.

Pitcairn

The four small islands in the southeast subtropical Pacific are a dependent territory of the United Kingdom. Pitcairn Island is a high rocky island and inhabited, but the neighbouring two atolls (Oneo and Ducie), and the raised coral platform, Henderson, are uninhabited. About 20 genera of corals have been reported, but other information is limited. Ducie has good coral cover on ocean-facing slopes, and corals are rare and seaweeds common off Pitcairn. Coral cover is low on the small fringing reef on the north side of Henderson. There

are few human impacts and the recent proposal to construct a dock and airfield on Henderson were not approved.

American Samoa

The Samoan islands are between Fiji and the Cook Islands in the central-south Pacific. American Samoa is a US territory to the east with five high volcanic islands and two atolls. Less than half the 50,000 people live outside the capital, Pago Pago Harbor, on the largest island Tutuila. The Swains atoll supports a few families, and Rose Atoll at the far east is uninhabited. The reefs are mostly fringing, with a small lagoon at Pala on the south coast of Tutuila. There are 300 species and 60 genera of coral.

The reefs were seriously degraded by a major crown-of-thorns starfish infestation between 1978 and 1980, followed by several large hurricanes during the last ten years. Shallow water reefs are showing healthy recovery, despite a widespread coral bleaching event in 1994. Airport construction off the south coast of Tutuila damaged reefs and beaches off Pala Lagoon, Coconut Point, and Nu'u'uli village. Current impacts include over-fishing on many reefs, and urban pollution in Pago Pago Harbor, including sewage discharges, tuna cannery wastes, chronic but small oil spills, sedimentation, and freshwater floods. Road construction on steep slopes exacerbates soil erosion and sedimentation, and rapid population growth and crowding along Tutuila's narrow coastal plain is resulting in development too close to the shoreline. Reefs at Rose Atoll were damaged in 1993 by a ship grounding and fuel spill. Three large MPAs have been established, and a small community college in Pago Pago, plus the three national agencies managing protected areas sponsor some reef research and monitoring.

Samoa (Western)

The remainder of the Samoan archipelago is independent with two large (Upolu, Savai'i) and several smaller high volcanic islands. Land area is larger than American Samoa, but fringing reefs are poor or absent off many coasts. Apia, the capital, is on Upolu's north central coast. There have been no detailed studies of the reefs but good surveys were done for reef fish and starfish infestations. Natural stresses have degraded reefs recently, including cyclones, starfish plagues, and coral bleaching. The major human stresses are urban pollution (sewage, trash, runoff, and coastal construction) near Apia, and over-fishing along many coasts. Dynamite fishing off Asau (Savai'i) was reported in the early 1970s using explosives stolen during construction of a new harbour. Early logging on Savai'i contributed to soil erosion and sedimentation on reefs. The move of the South Pacific Regional Environment Programme (SPREP) and a UNESCO office to Apia have expanded the limited opportunities for higher education and awareness about reefs. A single small marine protected area has been established (Table 1).

Tokelau

Tokelau is a territory of New Zealand to the north of Samoa in the central Pacific. The total land area of the three small atolls (Nukunonu, Fakaofo, and Atafu) is about 12 km^2, and the people follow a subsistence lifestyle. Heavy fishing is the only human pressure on the reefs, although there are proposals to blast small boat channels through the atoll perimeter. This could modify lagoon circulation, lower lagoon water levels, and expose many reef tops.

Tonga

This is a Kingdom in the south-central Pacific, southeast of Fiji and southwest of Samoa. It consists of 180 islands on a north-south axis. About 37 islands are inhabited, with Nuku'alofa on Tongatapu Island being the capital. There are three island clusters of raised coral islands and atolls with a few high volcanic islands: Vava'u group in the north; Ha'apai group in the center; and the Tongatapu group in the south. Coral reefs are well developed, but few scientific surveys have been conducted. The fisheries are better known.

The major natural stresses are severe tropical cyclones, cold temperatures, crown-of-thorns starfish infestations, and sea-level fluctuations during El Niño years. The major human stresses are concentrated at Tongatapu where siltation, causeway construction, coastal development, and sand mining have reduced lagoon circulation. This, combined with urban pollution, including sewage discharge, over-fishing, and destructive fishing, has severely damaged reef areas. Over-fishing and destructive fishing (with poisons and explosives) are problems on other islands as well. Tonga has established at least six marine protected areas, most off Tongatapu (Table 1).

Tuvalu

This is the world's smallest independent nation and consists of six atolls and three low coral islands, south of the Gilbert and Phoenix part of Kiribati and north of Fiji. Funafuti Atoll is the capital and was a large base during World War II, which resulted in much dredging and filling for port and airfield facilities. Recently, small boat channels were blasted through the reefs of several atolls under environmental guidelines developed by reef scientists, but there was some damage to corals and fish. There is some urban pollution in Funafuti lagoon, but the most serious concern is over-harvesting of subsistence fisheries. Tuvalu is vulnerable to damage from tropical cyclones, such as Hurricane Bebe in 1972.

Coral reef management in the south and east Pacific

Management strategies used by the governments in the region include:

- establishing coastal and marine protected areas to restrict access and some reef use;
- setting up fishery management areas and regulations to sustain the yields of reef fisheries;
- using environmental impact assessment for proposed developments to locate and design projects to minimize reef impacts;
- using coastal zone or coastal resource management to regulate occupation and use of coastal areas and resources;
- introducing environmental permits to control the introduction or disposal of pollutants including toxic and hazardous materials;
- formulating long-range land use and zoning plans to promote sustainability and compatibility among the often conflicting uses;
- maintaining and supporting traditional management and tenure regimes; and
- raising environmental awareness and education.

In the whole Pacific, only the US islands (Hawaii, American Samoa, and US Lines, Phoenix, and Wake) employ most of these strategies, and many island countries support only one or two strategies. Although traditional management of resources has worked successfully for thousands of years on most islands, the introduction of western cash or market economies, elected governments, and rapid population growth are rapidly eroding traditional methods across the Pacific. Therefore a greater reliance on other strategies will be needed to conserve reefs in the region.

Establishing marine protected areas (MPAs) is a popular and expanding strategy for managing coral reefs. More than 100 coastal protected areas have been established for the region, but about 40% do not give any protection to adjacent marine areas. Of the 60 true MPAs, 25 were established in the US and its territories (Hawaii, American Samoa, US Line and Phoenix Islands), and only 35 in the remaining 2500 major island and reef systems. In most of these areas, government surveillance and enforcement to protect marine resources is inadequate. Many Pacific island nations have been slow to set up protected areas because they are perceived as threats to local traditional land ownership and resource use that have been in effect for many centuries. However, if the process is truly integrated and

control of protected areas given to local people, supported by the national government, together with some financial compensation and education, then this cooperation results in better surveillance and enforcement.

The South Pacific Biodiversity Conservation Program of the South Pacific Regional Environment Programme (SPREP) is promoting community-based protected areas with funding from the Global Environment Facility. Assistance is also coming from other organizations (such as The Nature Conservancy, World Wildlife Fund), and universities (Universities of Hawaii, Guam, South Pacific, French Pacific, and Papua New Guinea), institutions (East-West Center, ORSTOM, IFREMER), and museums (Bishop Museum) with help from universities in Australia, New Zealand, Japan, and the US. SPREP is taking a lead role in environmental conservation with substantial funding from UNDP (United Nations Environment and Development Programme), World Bank, Asian Development Bank, and others. SPREP supports reef management through encouraging environmental impact assessment, coastal zone management, sea turtle conservation, environmental education, and waste management. The Pacific Science Association including its Coral Reef Committee is coordinating activities among Pacific scientists and recently assessed coral reef health within the broader Pacific region (including east Asia, southeast Asia, eastern Australia, and the west coast of the Americas). SPREP coordinated a particularly successful public participation campaign for the International Year of the Coral Reef (1997) and International Coral Reef Initiative (ICRI) meetings in 1996, 1997 and 1998.

Pacific Island governments, outside the US areas, have been slow to adopt reef management strategies such as integrated coastal management and environmental impact assessment (EIA), because there is a preference to use the 'Pacific way' rather than 'western' concepts of regulations and reef use. French Polynesia has recently adopted a management plan for maritime areas and EIA. The Cooks, and Kiribati are in the process of developing EIA or coastal management plans. Clearly a system of management has to be developed that incorporates both traditional and non-traditional ('western') systems of management, with the emphasis on reefs near urban areas.

Actions which need to be taken for the region

These are some suggested activities requiring cooperation among scientists and non-scientists to achieve success:

- better marine environmental education to stress the importance of coral reefs and their conservation;

- capacity building: training Pacific islanders to manage, monitor, and educate others about coral reefs;
- coral reef monitoring: measure baselines and trends on coral reefs to convince decision-makers and politicians to take action;
- establish more marine protected areas, especially on uninhabited or sparsely inhabited islands, before population pressures damage them;
- community-based management so that local communities lead and get and collaborate with governments to manage development and control resource exploitation on their 'home' reefs;
- better environmental impact assessment, and research on reef restoration, especially near urban areas, heavily used protected areas;
- integrated coastal management: putting all the above together and getting all stakeholders involved; and
- population control: this is especially important for Pacific islands, with a need for considerable public awareness, education, and giving the power to the women.

Developing regional centres of excellence for education, research and planning to enhance conservation of coral reefs

It would be advisable if several of the small island states with limited land area, but broad ocean jurisdiction, could cooperate as a federation to exert more political and economic influence and better protect their coral reefs. Other than marine resources, these states have limited economic potential and capacity to monitor and protect these ocean resources from the population and market pressures of their larger Asian and Pacific neighbours. From a management perspective, the capacity and power of a small islands federation would be greater than the sum of the parts. Such a federation could insist on improved surveillance, monitoring, and enforcement regimes, demand greater compensation for fisheries exploitation, and insist on effective sanctions against countries whose fishers engage in unauthorized and destructive fishing practices. The federation would also be more effective in seeking aid for capacity building, education, and training to improve conservation of coral reefs and other marine resources.

Table 1. Existing protected areas for oceanic island and/or adjacent coral reefs in the southwest and east Pacific. Protected areas with an asterisk (*) exclude marine areas.

MELANESIA

FIJI

Vuo, Draunibata, and Labiku islets

KERMADEC ISLANDS (NZ)

Kermadec Islands Marine Reserve

NEW CALEDONIA

Reserve Speciale de Fauna et de Flore de l'Ilot Maitre (RS)
RS Tournante de Faune Marine
RS Marine Yves Merlet
Parc Territorial de Lagon Sud (Amedee, Bailly, Canard, Laregnare, Signal)
RS de Faune de l'Ile de Pam
RS de Faunae de l'Ilot Represdour
Southern Botanical Reserve (Cap Ndua)

PITCAIRN ISLANDS (UK)

None

SOLOMON ISLANDS

No strict reserves but some protected areas.

Arnavon Islands
Tulagi Island Bird Sanctuary (BS) *
Oema Atoll BS *
Mandeleana BS *
Dalakalau BS *
Dalakalonga BS *

TONGA

Eua' Island National Park *
Fanga'uta and Fangakakau Lagoons Marine Reserve
Hakaumama'o Reef Reserve
Malinoa Island Park and Reef Reserve
Monuafe Island Park and Reef Reserve
Pangaimotu Reef Reserve

VANUATU

White Sands Recreational Reserve (RR) * on Efate
Aore — Bukaro RR (2) * on Espiritu Santo
Naomebaravu RR (2) * on Malo
President Coolidge and Million Dollar Point Marine Reserve
Narong Marine Reserve

Table 1. (continued)

POLYNESIA

AMERICAN SAMOA (US)
- American Samoa National Park (Tutuila, Ta'u, Ofu)
- Fagatele National Marina Sanctuary (Tutuila)
- Rose Atoll National Wildlife Refuge

EASTER ISLAND (Ecuador)
- Isla de Pascua National Park (Easter or Rapa Nui) *
- Isla Sala y Gomez Nature Sanctuary *

COOK ISLANDS
- Avatiu Foreshore Reserve (Rarotonga)
- Suwarrow Atoll National Park* (? New status as pearl farm)

COSTA RICA
- Parque Nacional Isla del Coco (Cocos)

GALAPAGOS (Chile)
- Reserva de Recursos Marinos Galapagos
- Sanctuario de Ballenas de Galapagos

FRENCH POLYNESIA

Marquesas:
- Eiao Island Territorial Reserve (TR)
- Hatutaa Island TR
- Mohotani Island TR
- Motu One Island TR

Societies:
- Manuae (Scilly) TR
- Te Faaiti Natural Park (Tahiti) *

Tuamotus:
- Taiaoro Atoll Biophere Reserve/ W.A. Robinson Réserve Intégrale

HAWAIIAN ISLANDS (US)

Hawaii Island:
- Hawaii Volcanoes National Park (NP)
- Kaloko-Honokohau National Historic Park (NHP)
- Kealakekua Bay, Marine Life Conservation District (MLCD)
- Lapakahi, MLCD
- Old Kona Airport MLCD
- Puu Kohola NHP
- Pu'uhonua o Honaunau NHP

Table 1. (continued)

Waialea Bay MLCD
Waimanu Valley Nat Estuarine Research Reserve
3 offshore island seabird sanctuaries (OISS)*

Kahoolawe Island:
Hawaiian Islands Humpback Whale National Marine Sanctuary

Kauai Island:
Mililii State Park (SP)
Nualolo Kai SP
3 OISS *

Lanai Island:
Hulopoe-Palawai-Manele MLCD
4 OISS *

Maui Island:
Honolua and Mokuleia Bay MLCD
Kinau-Ahihi-La Perouse Natural Area Reserve
9 OISS *

Molokini Shoal MLCD

Molokai Island:
Kalaupapa NHP
6 OISS *

Northwest Hawaii Islands: National Wildlife Refuge (NWR)
2 OISS *

Oahu Island:
Coconut Island Hawaii Marine Lab. Refuge
Hanauma Bay MLCD
Pupukea Beach MLCD
Waikiki MLCD
13 OISS *

OTHER US (LINE ISLANDS)
Baker Island National Wildlife Refuge (NWR)
Howland Island NWR
Jarvis Island NWR
Johnston Island NWR

NIUE
none

Table 1. (continued)

SAMOA (WESTERN)
Palolo Deep Marine Reserve on Upolu

TOKELAU (NZ)
none

TUVALU
none

WALLIS AND FUTUNA (France)
none

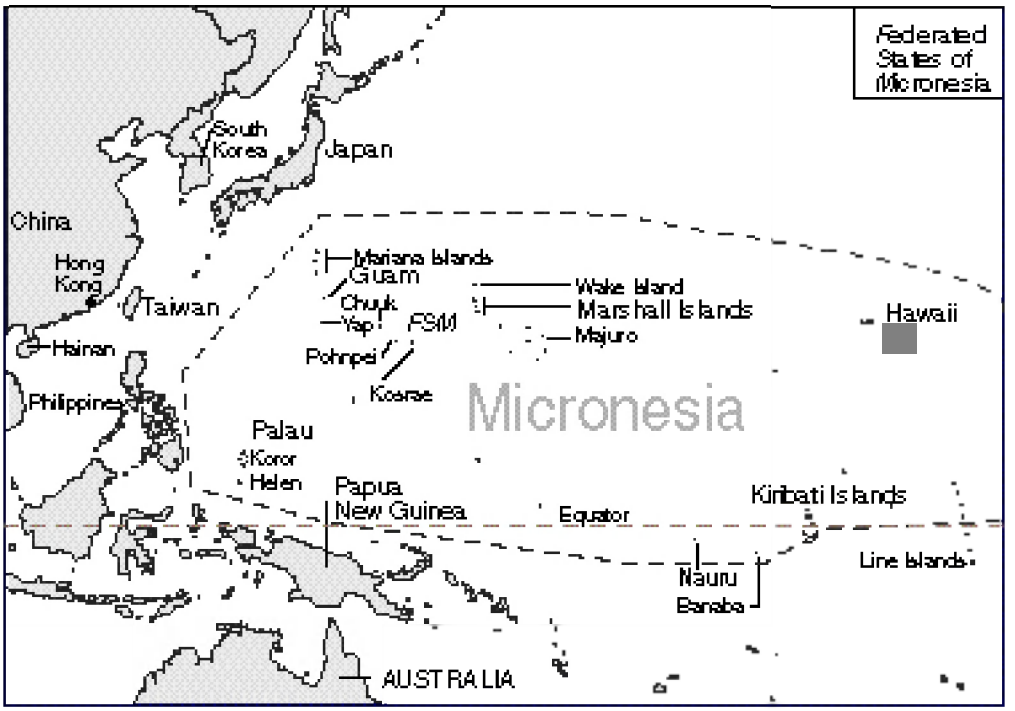
Jim Maragos is with the Program on Environment at the East-West Center, Honolulu, Hawaii, USA

7B. Status of coral reefs in the northwest Pacific Ocean: Micronesia and east Asia

Jim Maragos, Charles Birkeland and Gregor Hodgson

Abstract

The reefs vary from those in near pristine condition where there have been few human impacts, to many that are seriously degraded and continuing to degrade. Those reefs off the mainland of China, Japan, and Taiwan have been damaged by sediment and pollution, and are subject to some of the heaviest fishing pressures in the world, including blast and cyanide fishing. Reefs are also heavily impacted by regular typhoons and plagues of crown-of-thorns starfish, and most show major reductions in living coral cover. Few reefs have reproductive-sized fishes. Reefs of the Marianas Archipelago have also deteriorated in both coral cover and fish populations. By contrast, the reefs of Palau, the Federated States of Micronesia, and the Marshall Islands are generally in good health, with serious degradation only around population centres where there is sediment and nutrient pollution. Fishing



activity has traditionally been light to moderate, however, there is an almost insatiable demand from Asian and American markets for quality reef products, and fishing pressures are increasing dramatically. Giant clams, sea cucumbers, trochus shells, lobsters, and many of the top quality fish are being depleted on even remote reefs, and there is increasing evidence of destructive fishing (dynamite and cyanide). No reefs in the region are adequately managed, but reef conservation is receiving higher priority in all countries, though the countries use widely differing management strategies. Unless there are concerted efforts to reduce stresses on reefs by reducing human activities and applying sound resource management, there will be a continuing trend of reef degradation.

Introduction

The Pacific basin has been divided into four regions with two in each essay. These divisions are based on the culture of the peoples who settled these islands, and geographic locality. Northeast Asia and Micronesia (northeast tropical Pacific) are covered in this essay. The companion essay covers Melanesia, in the southwest Pacific, and Polynesia in the east Pacific. There is a wide range of countries, from those with massive populations like China, to those with small populations like Palau; and from the wealthy, like Japan and Guam, to developing countries in Micronesia.

Status of reefs in the northwest Pacific

The condition of reefs in this region range from near pristine with few human impacts, to many reefs that are seriously degraded with pressures increasing on them. The reefs off China have been heavily damaged by sediment runoff from floods of the large rivers of the mainland. Fishing pressures are also amongst the highest in the world, along with massively increasing pollution. The reefs of Taiwan are similarly affected, but at a reduced scale, however there are concerted efforts to conserve some of the reef resources. There has been a decrease from 50% living coral cover to 30% during the past decade. Japanese reefs are also chronically damaged by sediment and nutrient pollution, as well as heavy fishing pressures. There has been a policy to line many rivers and much of the coastline with concrete, such that reefs have been damaged directly, or inundated rapidly with fresh water. Indeed, 19% of Japanese reefs have been removed. The effects of a large crown-of-thorns starfish plague in the late 1960s are still seen on many reefs. Between 1972 and 1981–1984, there was decrease in coral cover on 55 of 76 sites in the Ryukyu Archipelago. Reef conservation, however, now has a much higher priority in Japan.

Reefs of the Marianas have generally deteriorated. Since 1981, about 5% of 113 sites around Guam have shown living coral cover over 50%. Coral recruitment has significantly

decreased over this time, and over-fishing has reduced the size of fish so much that the reproductive potential of fish is only 5% of what it once was.

The other reefs of Micronesia (Palau, Federated States of Micronesia, and the Marshall Islands) are in much better health, with some damaged reefs around population centres because of sediment and nutrient pollution. Local fishing pressures are slight to moderate, however, there is clear evidence on some reefs of destructive fishing (use of dynamite which smashes corals in a circular area). On most reefs, there is the virtual extinction of giant clams, sea cucumbers, trochus shells, lobsters, and many of the top quality fish.

Natural stresses to northwest Pacific reefs

The stresses are similar to the preceding chapter with tropical typhoons (cyclones) and long-fetch ocean waves being the major physical factors that influence reef growth. There are on average 17.8 typhoons (or hurricanes or major cyclones) each year in the Western Pacific Monsoon Trough, which starts in southern Micronesia and hits places between the Philippines to the south and Okinawa to the north. Guam is in the approximate centre of this typhoon highway, and has been impacted every year on average by a major typhoon. These generate heavy waves, such that the corals on these reefs are very rugged and compact, with few large colonies in shallow water. Many of the islands in the Federated States of Micronesia and southern Japan are gradually subsiding, simulating sea level rise. This will compound the effects of global climate change in these areas. Freshwater runoff with increased amounts of sediment and nutrients have damaged the reefs around high islands, particularly in lagoons and shallow bays, for example Pohnpei in the Federated States of Micronesia, the large islands of Palau, Guam, and southern Japan. The crown-of-thorns starfish (Acanthaster) has had a particularly devastating impact on the reefs of southern Japan, and many reefs have not recovered since the outbreaks of the late 1960s.

Human stresses to northwest Pacific reefs

Human pressures on coral reefs increase towards the highly populated areas in the west, being particularly high off Asia, and less in the Marshalls and Kiribati. Nutrient (sewage) and sediment pollution is higher near the larger populations, for example Japan, and Taiwan, and lower in the low islands and atolls of the east. Pollution effects are also greatest in atoll lagoons, particularly where circulation is sluggish, and near large towns, for example Tarawa (Kiribati), and Majuro (Marshall Islands). Much of Micronesia suffered major military impacts during the World War II along with coastal construction, particularly the building of airports over coral reefs and construction of ports. The effects of nuclear and missile testing can still

be seen on some atolls, for example Bikini, Enewetak, Kwajalein (the Marshalls) and Kanton, Christmas, Malden (Kiribati). Stressed reefs have been unable to recover from Acanthaster plagues in Okinawa and other Ryukyu Islands of Japan.

A rapidly increasing problem in the Pacific, particularly in the west near Asia, is the use of destructive fishing practices, especially blast (dynamite) fishing, poisons (cyanide, bleach) and unattended gill nets. The high demand for fisheries products in Asia has resulted in the accelerated stripping of giant clams, sea cucumbers, trochus, shark (for their fins), sea turtles, and coconut crabs off many west Pacific reefs, and even more remote reefs in the Central Pacific. The explosive demand for live reef fish for the restaurant trade in Hong Kong and other Chinese cities has fuelled an industry based on stunning large fish with cyanide and transporting them in tankers. This has resulted in the local extinction of many reef fish and a trail of dead coral reefs.

Northeast Asia

This region covers sub-tropical East Asia, to the north of Vietnam and the Philippines, and includes China (including Hong Kong), Japan, Korea, and Taiwan. Most of the coral reefs grow around volcanic islands, with some on the continental shelf. The major reefs are those of Japan, which extend in an arc from the Ryukyus, just to the east of Taiwan, north to the main islands. As well, Japan has the Bonin Islands (a continuation of the Marianas Chain), and the distant Marcus islands (Minami-tori Shima) 3500 km east of Taiwan. The reefs of Taiwan are mostly fringing reefs with some platform reefs. Scattered coral communities and some reefs occur off the southeast corner of mainland China, including Hong Kong and islands to the north, and Hainan Dao island and the Xisha Qundao islands to the south. There is little information for many of the Chinese reefs, except for Hong Kong. To the south of Korea, there are some coral communities growing on rocky islands.

Most of the coral reefs of northeast Asia are heavily exploited, due to very high population densities and market demand for seafood. Reefs near urban centres are over-exploited and remote reefs are also heavily fished, often with destructive fishing methods. The pressures on these reefs and the amount of damage that occurs will increase with dramatically increasing populations and economic growth in East Asia. Tourism is also increasing markedly on many tropical and subtropical islands of Japan, Taiwan, and China, and this is adding stresses to reefs. The principal natural stresses include typhoons, occasional tsunamis, earthquakes, volcanic eruptions, Acanthaster outbreaks, water temperature fluctuations, and occasional episodes of freshwater flooding.

China and Hong Kong Special Administrative Region

The two types of coral reefs, fringing and offshore atolls, of the South China Sea are very different in status and administration. Little is known of the offshore reefs, particularly since the sovereignty of many of the Paracel and Spratly Islands are politically disputed. These reefs are remote from land influences, but are fished heavily and impacted by military activities.

Corals grow from the border with Vietnam, north to Xiamen (Fujian Province, 24°N), however, there are no coastal reefs north of Guangdong Province (23°N). There are very well-developed coral reefs off southern Hainan Island (18°N). All Chinese reefs are heavily exploited for fish and shellfish, and most have been damaged by pollution, sedimentation, over-fishing, especially cyanide and blast fishing. The reefs in Yalong Bay off Sanya City in Hainan are an exception and, have been set aside as a reserve. These reefs have a high (80–90%) coral cover and diversity, and cooperation between hotel operators and the Hainan Marine Department in 1998 resulted in good protection against illegal fishing. Unfortunately, there are few marketable-size fish because other forms of fishing are still allowed, but the corals are in good condition. The first Integrated Coastal Management project in China started in 1997 (funded by UNDP), with sites in the coral reef provinces of Guangdong, Guangxi and Hainan. These provinces established high-level Coastal Management Committees to plan coastal development and conserve coral reef biodiversity. The Hainan Marine Department acknowledges the economic value of reefs and is creating a functional zonation scheme for Sanya reefs.

The Hong Kong Special Administrative Region (SAR) was created in 1997 when the British colony returned to China. Hong Kong reefs were first surveyed from 1990–1995 by consultants for the Civil Engineering Department, and then by university teams, Reef Check, and the Agriculture and Fisheries Department. The reefs have been badly damaged by sedimentation, sewage, and over-fishing, with blast fishing occurring despite active police work. Most high-value edible species are locally extinct. Many of the best reefs were severely damaged during 1994 when high Pearl River discharges resulted in upwellings, and plankton blooms. Up to 80% of corals died below 4 m when oxygen levels dropped; there was lower mortality in shallow water. Bleaching in 1998 has caused some mortality, primarily of Acropora in shallow water. New marine parks were set up in 1997 to protect small parts of some of the best remaining reef areas in Mirs Bay in the northeast, however, there are no fishing restrictions, so reef fish will remain scarce until the rules are changed. Many artificial reefs have been built with concrete 'reef balls', old ships, and blocks, with plans to cover a sizeable area of muddy-bottom.

Japan

The warm Kuroshio Current ensures that coral reefs can grow from 24°N to 30°N, and large coral formations grow as far north as 35°N, near Tokyo. Reefs in the south are flourishing fringing and patch reefs in the Ryukyu Archipelago. These reefs have a high diversity of corals (400 species) with many endemic species. Tropical cyclones commonly batter the coastline of southern Japan every few years, but reefs have developed either in sheltered areas or with wave resistant structures. Crown-of-thorns starfish infestations devastated Okinawa reefs in 1969 and have been a chronic problem since then.

There are serious concerns about the status of Japanese reefs, with about one third of coral species at risk of becoming locally extinct. About seven complete reefs (19% of Japan's coral area) were removed between 1981 and 1990 by dredging and blasting to make boat harbours or breakwaters. Agricultural practices in Japan have been particularly polluting with sediment and fertilizer nutrients. Another harmful practice is straightening rivers and lining them with cement. This increases water and sediment flows onto coral reefs (and also prevents replenishment of groundwater for agriculture). The reefs off the main island of Okinawa have very low coral cover, and did not recover after the crown-of-thorns starfish plague in 1969, because of continual nutrient and red clay sediment pollution. In addition fishing pressures have been high, such that sea-urchin populations have exploded because their normal predators have been removed. These urchins are scraping away the coral rock base of the reefs and preventing new coral recruitment.

Living coral cover on Ryukyu coral reefs is seriously diminishing; 63% of sites have less than 10% living coral, and only 2% have over 50% live coral cover (Table 1). The Environment Agency of Japan noted that only 8% of reefs had excellent coral cover. The Agency has implemented plans for greater protection of coral reef resources and is planning a large coral reef conservation centre in Okinawa. There are six marine protected areas with coral reefs, including approximately 11% of the coral reef area. The World Wide Fund for Nature Japan is investigating ways of improving land management to reduce redsoil runoff. Local fishermen are becoming increasingly active in managing reefs and removed 81,000 crown-of-thorns starfish (28 tons) in six days during 1996.

Table 1. The status of coral reefs in the Ryukyus (Japan), Guam, and Taiwan measured at different times to show the status and downward trend. The table shows the percentage of reefs that were surveyed (No. of reefs) that have coral cover within three ranges Low (less than 25% coral cover), Medium (between 25% and 50% coral cover) and High (over 50% coral cover).

Country	No. of reefs	Year	Low <25%	Medium 25–50%	High >50%
Ryukyus	n = 84	1972	30	23	47
	n = 224	1981–1984	87	11	2
	n = 20	1990	70	20	10
Taiwan	n = 113	1992–1995	50	27	23
Guam	n = 113	1972–1990	78	16	6

Korea

There are no true coral reefs, but around the Chejudo islands (140 km south of the Korean peninsula) there are coral communities which are particularly rich in soft corals. Plans to protect these islands as MPAs were strongly opposed by the fishing lobby.

Taiwan

There are extensive fringing reefs and some platform reefs around the main island and some smaller islands. The species diversity is relatively high, with about 300 hard coral species, 70 soft coral and gorgonian species, and 1200 fish species. The reefs are heavily impacted by cyclones and also have been invaded by crown-of-thorns starfish. There has been substantial damage to the reefs during the past ten years, with living coral cover being reduced from approximately 50% to 30% and some species of reef fish, gastropods, and crustaceans becoming locally extinct. Destructive fishing practices (especially dynamite), sedimentation from construction and dredging, coral collection, sewage pollution, aquarium fish collecting, and unregulated tourist activities have caused this damage. Reefs in the Penghu Islands (west of Taiwan on the Tropic of Cancer) have been extensively damaged by dynamite fishing, trawling, and sedimentation. The Lu-tao and Lan-yu reefs (southeast of Taiwan) are being damaged by sedimentation and intense tourist activities. Reef fish populations are very low because of aquarium fish collecting and spearfishing.

Encouragingly, the Taiwanese government and scientists are promoting sustainable use of the coral reefs and seven coastal conservation zones have been established by the National Park Department within the Ministry of Interior.

MICRONESIA

The eight governments in the region (the Federated States of Micronesia [FSM], Guam, Kiribati, Marshall Islands, Nauru, Northern Mariana Islands, Palau, and Wake Island [USA],) consist of islands scattered over a large area in the central and northwest tropical Pacific. Volcanic islands in Micronesia are limited to the five clusters in the Caroline islands just north of the equator, and the 20 Mariana islands further northwest. The remaining Micronesian countries or governments consist entirely of coral islands or atolls. There are 82 atolls concentrated in the FSM, Marshall Islands, and Kiribati. Kwajalein in the Marshalls is the world's largest atoll lagoon. There are two large barrier reefs: Chuuk (FSM); and the main Palau islands; with a smaller barrier reef at Pohnpei (FSM). Uplifted coral islands are confined to the main Palau islands, and Nauru and Banaba, west of the Gilberts. Stable sea levels or gradual subsidence characterizes the central and eastern parts of the region, promoting atoll reef and some barrier reef development. Stony coral diversity is high in the west (Palau) with over 300 species present but drops off to less than 200 species in eastern Micronesia (Kosrae Island [FSM], Kiribati).

The Micronesian countries consist of five island groups: the Mariana Islands, including Guam and the Northern Marianas; the Carolines (including Palau in the west and the FSM); the Gilbert-Marshalls chain (including the Marshall Islands, Wake, Nauru, and the Gilbert portion of Kiribati); and the rest of Kiribati in the Phoenix Islands; and the Line Islands on the other side of the Date Line. Many of the typhoons that hit east Asia are generated in the southern parts of Micronesia and only develop into destructive storms as they move north and west towards the Marianas and Philippines.

Federated States of Micronesia (FSM)

This has the largest population in Micronesia and second largest land and sea area. There are four states, each with a volcanic high island cluster (Yap, Chuuk, Pohnpei, Kosrae) surrounded by 40 atolls and low coral islands. The four urban centres (Colonia, Chuuk Lagoon, Kolonia, and Lelu-Tofol) are the state capitals, with Kolonia on Pohnpei as the national capital. During the past century, FSM coral reefs suffered from soil erosion resulting from logging, agriculture, major coastal construction (dredging and filling), military occupation, and World War II battles. Sunken Japanese warships in Chuuk lagoon now serve as artificial reefs, and are popular with diving tourists. Urban pollution and coastal development continue as the major threats, along with poaching of giant clams, sharks, trochus, and other commercial species from remote reefs. Reef damage is most obvious around the rapidly expanding populations on the large islands. At some sites surveyed recently in Chuuk lagoon (and perhaps elsewhere), blast fishing has lowered coral cover.

The Community College of Micronesia on Pohnpei is a regional centre for education, and reef research, along with the Yap Institute of Natural Science, and there are mariculture facilities in Pohnpei and Kosrae. No reefs in the FSM are given complete protection, but seasonal fishing limits are imposed on trochus harvesting. Dive operators protect the shipwrecks in Chuuk lagoon, as these are part of rapidly growing adventure tourism in all four states.

Guam

A territory of the USA, Guam is the largest and most populous island in Micronesia, at the southern end of the Marianas chain. Agana is the capital on the west coast. Guam has two different structures: a high volcanic; and raised limestone part, and has mostly fringing reefs and two barrier reefs (Apra Harbour and Merizo Lagoon). Urban tourism, and military development have modified much of the shoreline and reefs on the central west coast. There is extensive military development on the northern end, and most tourism is on the southern end. Many reefs were also damaged during the war, but have since recovered. The University of Guam and its Marine Laboratory are the major centres for higher education and reef research in Micronesia. Recently Guam established several marine and coastal protected areas (Table 2).

The fringing reefs around this large island have deteriorated since the late 1970s. Corals used to recover from natural damage, such as crown-of-thorns predation and typhoon waves within 12–15 years (from 1% living coral cover to over 60%). In the 1960s and 1970s finding over 50% living coral cover was common; now only 7 of the 113 surveys done in the 1980s and 1990s had over 50% living coral cover, and 78% of surveys showed less than 25% living coral cover. The number of new coral recruits has dropped significantly since the 1970s. Over the same time, there was a similar decrease in fish populations. Between 1985 to 1997, the total catch per unit effort decreased by 78% and also the fish do not produce nearly as many larvae, because the size of fish have been reduced (reproductive potential of the fish population dropped by 95% between 1984 and 1991). The major algal-grazing fishes (scarids, acanthurids, and siganids) have been specially targeted by fishermen and the massive reduction in populations correlate with increases in algal cover, decreases in coral recruitment, and decreases in cover of living coral.

Another major change on Guam is the increased rates of sediment runoff, for example the sediment flowing out of the Ugam River doubled from 1975 to 1993. This was because of poor agriculture, and development, and also because hunters burn large areas every year, so now sediment flow is 243 tons per acre per year.

Table 2. Existing protected areas for oceanic island and/or adjacent coral reefs in the northwest Pacific. Protected areas with an asterisk (*) exclude marine areas.

NORTHEAST ASIA	
CHINA – HONG KONG (SAR)	
	Double Haven Marine Protected Area (includes Mirs Bay HK)
	Cape D'Aguilar Marine Protected Area (HK)
	Hoi Ha Wan Marine Protected Area (HK)
	Sanya Coral Reef National Marine Nature Reserve (Hainan)
JAPAN	
	Ogasawara National Park
	Iriomote National Park
	Amami Islands Quasi — National Park
	Okinawa Beach Quasi — National Park
	Okinawa Old Battlefield Quasi- National Park
	Kume-jima Natural Park
TAIWAN	
	7 coastal conservation zones
MICRONESIA	
FEDERATED STATES OF MICRONESIA	
	Chuuk Atoll, shipwrecks historic monument
	Kosrae Island
GUAM	
	Haputo Ecological Reserve Area
	Orote Ecological Reserve Area
	Guam Territorial Seashore Park
KIRIBATI	
	Birnie Island Wildlife Sanctuary (WS) *
	Caroraina (Caroline) Atoll WS
	Cook Islet Conservation Area (Kiritimati) *
	Malden Island WS *
	McKean Island WS *
	North Tarawa Conservation Area (Tarawa)
	Rawaki (Phoenix) Island WS *
	Starbuck Island WS *
	Vostok Island WS
MARSHALL ISLANDS	
	Bokaak Atoll, leased protected area
	Pikaar Atoll, leased protected area
NAURU	
	None
PALAU	
	Ngerukewid Islands Wildlife Refuge
	Ngerumekaol Grouper Spawning Area

Kiribati

These islands have the largest land area and maritime jurisdiction in Micronesia. There is one raised limestone island (Banaba) and 35 additional low coral islands and atolls in three island clusters in the far west. The 16 Gilbert or Tungaru Islands are the largest group, and home islands of the Kiribati culture; the ten Phoenix and nine Line Islands are the two other clusters further to the east, which were only inhabited during the last century. Kiribati laborers were sent to these islands, and they became part of the Republic of Kiribati in 1979, with four of the wetter islands permanently occupied (Kanton, Kiritimati, Tabuaeran, and Teraina). There were previous failed attempts to settle the others, although the government is again proposing to settle some of these arid islands to relieve population pressures on the main islands. More than half of the land is on Kiritimati (Christmas) atoll in the northern Line Islands, and these, plus the nearby atolls of Tabuaeran and Teraina, are targets for population resettlement.

Tropical cyclones rarely affect these islands and there are few other natural stresses. In general, the reefs are in excellent condition, except for damage around population centres. Some reefs, for example Tarawa, were severely damaged or modified during World War II. Major effects now are from urban pollution and road and causeway construction at Tarawa and several nearby atolls, resulting in changes to current flows and pollution of lagoons. Kiritimati and Malden were used for atmospheric nuclear testing about 40 years ago. Phosphate mining has stripped Banaba, and guano mining during the past century has also modified many of the arid uninhabited islands. Fishing pressure is high on reefs around the heavily populated atolls. Plans to establish space-shuttle facilities and tourist resorts on Kiritimati, and to settle some of the uninhabited islands, may cause depletion of reef species and damage some reefs. Kiritimati and several of the Phoenix Islands are wildlife reserves, and the government has established nine marine and coastal protected areas. Small marine protected areas are proposed for Kiritimati, Tarawa, and perhaps Caroline atoll. The University of the South Pacific in Fiji established the Atoll Research Centre in Tarawa as the only research and higher education facility in Kiribati.

Marshall Islands

The Republic of the Marshall Islands consists of five low coral islands and 29 atolls, with many being very large. Seven of the northern arid atolls are uninhabited, and most of the population lives on the southern wet atolls. There are large towns on Majuro (the capital) in the south and Kwajalein Atoll in the centre. Population is growing very rapidly, and some of the uninhabited atolls are targeted to reduce population pressure on the more crowded atolls. Wake Atoll, in the far north is a US military base.

There are few natural stresses to these reefs, but several atolls (Wake, Enewetak, Jaluit, Mili, and Kwajalein) were devastated during the last war, and by more recent nuclear testing on Bikini and Enewetak Atolls. These reefs have largely recovered, but the nuclear test islands are still contaminated. Urban pollution is severe on Majuro and Kwajalein Atolls, including Ebeye Island, probably the most crowded island in the world. The US military uses Kwajalein and Wake Atolls for missile testing and these developments cause some reef damage through dredging of coral sand and rock, and in-filling to create and develop new land. Large holes excavated in the reef flat pavements of Majuro, Bikini, and Kwajalein, were quickly recolonized by corals, showing that these pavements were good for coral growth, if protected from waves.

The Mid-Pacific Marine Laboratory on Eniwetak Atoll was abandoned in the late 1970s and current science and higher education are provided by a small marine science program of the College of the Marshall Islands in Majuro. The government recently established its first two marine protected areas (Table 2).

Nauru

This is a single raised limestone island just west of the similar island of Banaba. Both islands were mined extensively for phosphate rock for many decades, but mining is currently active only on Nauru. Reef growth is limited to the narrow and steep ocean faces around the cliff-like shoreline. The main human impacts are associated with coastal construction and operations of the port exporting the phosphate rock. There is also some spillage of oil, phosphate dust, and some sewage pollution, but fishing is limited because the steep slopes are fully exposed to ocean waves.

Northern Mariana Islands

These northern islands form a Commonwealth of the USA, and consist of about 20 islands and reefs, north of Guam in the northwest corner of Micronesia. The largest islands (Saipan, Rota, and Tinian) are in the south, and consist of high volcanic islands capped or surrounded by limestone terraces. The capital is on Saipan's west coast at Garapan. Scattered fringing reefs are common along the main southern islands, with a barrier reef off Garapan. Elsewhere reefs are absent or submerged, although extensive reef development occurs around Farallon de Medinilla. Saipan was extensively bombed during World War II, but there is little evidence of damage now to those reefs. Tourism is the main economic activity on Saipan with more development planned on Rota. Tinian is earmarked for future military use.

The reefs are subjected to many natural stresses, especially typhoons, heavy prevailing seas, earthquakes, some lava flows, and colder waters on northern reefs. Harbour and shoreline development is concentrated off Western Saipan, with docks also on West Rota and

southwest Tinian. Urban pollution, sedimentation, some flooding, and over-fishing are stresses near populated areas, but heavy and often destructive fishing (poisons, dynamite) occurs along many other coasts. Farallon de Medinilla was a bombing range for many years. Several islands declared as wildlife reserves may include marine areas, and the reefs off Managaha Island may also be protected (Table 2).

Palau

These are a complex cluster of volcanic islands in the north and raised limestone islands (including the 500 famous, small 'rock islands') in the south, all surrounded by an extensive barrier reef. There are also two outlying atolls (Kayangel, Ngeruangl) and one large submerged atoll-like reef (Velasco) up to 50 km north, and a raised limestone island (Angaur), five low coral islands and one atoll (Helen) up to 600 km to the south.

There are few natural stresses on these reefs, which largely remain in excellent condition. Several of the larger islands have been connected by bridges and causeways (Koror, Malakal, Ngeresbeskang, and southern Babeldaob, the largest island), that interfere with current flow. The population is relatively small, but extensive road and coastal development is under way to shift more population and tourism to Babeldaob, the new capital. There is localised reef damage from this soil erosion, plus sewage pollution and solid waste disposal around the towns, and the export of reef fish for food and aquariums. Sport diving and tourism is growing at an alarming rate, and poorly designed development is resulting in reef damage.

The Japanese Palao Biological Station was abandoned during World War II, and there are plans to build a combined Japanese-American marine biological laboratory in the capital. This will complement the existing mariculture research centre. The government has established a marine protected area (Table 2). The Palauans had a strong culture of marine conservation and the Palau Conservation Society is working with the government, landowners and communities to establish additional reserves. Several seasonal harvest reserves for trochus have been set up on the main islands.

Reef management in the region

There are quite large differences in the management strategies used by the governments in the region. These differences reflect the different cultures and population densities, and the different extent and status of reef resources. The countries with the most active strategies for management are Guam, and the Northern Marianas. The emphasis for reef conservation is increasing in Japan and Taiwan as both the economies and conservation ethic expand. There is,

however, little interest in reef conservation in China and the other Micronesian states of Kiribati, Federated States of Micronesia and the Marshall Islands and Palau. These Micronesian countries still retain considerable levels of traditional management, but this is steadily being eroded.

Actions which Need to be taken for the region

These are some suggested activities requiring cooperation among scientists and non-scientists to achieve success:

- Better marine environmental education to stress the importance of coral reefs and their conservation;
- Capacity building: training Pacific islanders to manage, monitor, and educate others about coral reefs;
- Coral reef monitoring: measure baselines and trends on coral reefs to convince decision-makers and politicians to take action;
- Establish more marine protected areas, especially on uninhabited or sparsely inhabited islands, before population pressures damage them;
- Community-based management, so that local communities take the lead and also collaborate with governments to manage development and control resource exploitation on their 'home' reefs;
- Better environmental impact assessment and research on reef restoration especially near urban areas, and heavily-used protected areas;
- Integrated coastal management: putting all the above together and getting all stakeholders involved;
- Population control: this is especially important for the Pacific islands, where there is a need for considerable public awareness and education, and a need to give power to the women;
- Developing regional centres of excellence to enhance conservation of coral reefs.

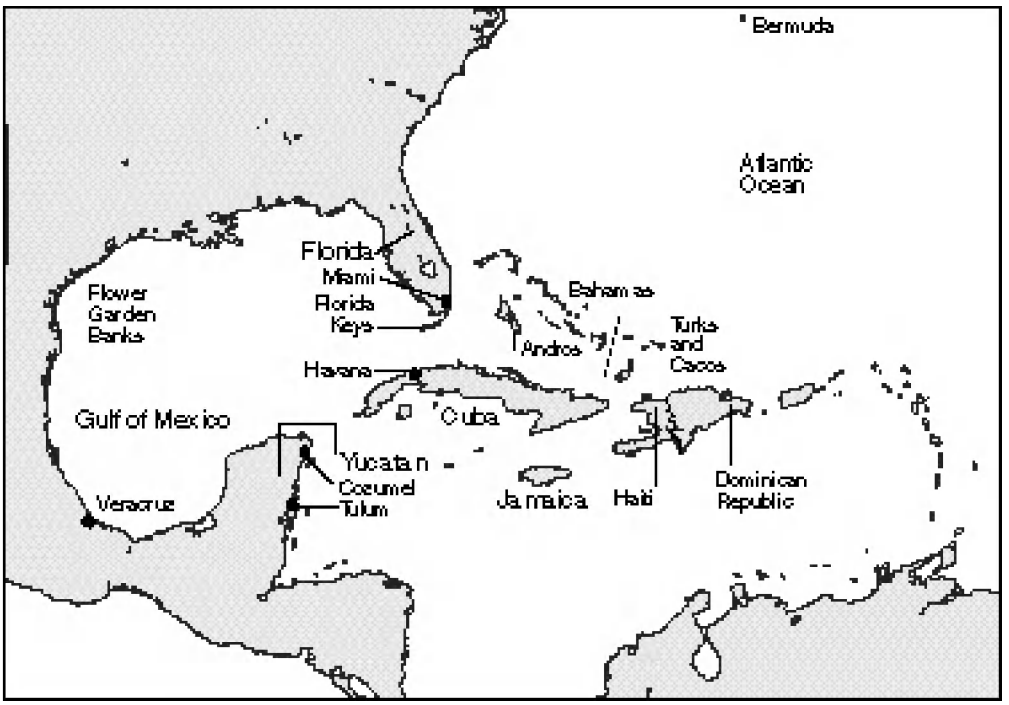
Jim Maragos is with the Program on Environment at the East-West Center in Hawaii, Charles Birkeland is at the University of Guam Marine Station, and Gregor Hodgson works in the Institute for Environment and Sustainable Development at the Hong Kong University of Science and Technology.

8. Status of coral reefs in the northern areas of the wider Caribbean

Judy Lang, Pedro Alcolado, Juan Pablo Carricart-Ganivet, Mark Chiappone, Al Curran, Phil Dustan, Gudrun Gaudian, Francisco Geraldes, Steve Gittings, Robbie Smith, Wes Tunnell and Jean Wiener

Abstract

Most of the reefs in the northern area of the wider Caribbean (NAWC) are in fair to relatively good condition, with few examples of marked reef degradation. Reef growth in some areas is naturally limited by temperature extremes (especially cold snaps), the influence of the North American continent, and/or upwelling. Hurricanes often have a major impact on exposed reefs. White-band disease (affecting Acropora spp.) has reduced live coral cover on many reefs during the last several decades. Stony corals have been degraded or lost on a few reefs near large cities in Cuba and Hispaniola, near Veracruz (Mexico) and in the



Florida Keys. Many reefs in less densely populated areas are relatively undisturbed by human activities, apart from fishing, and would be vulnerable to increased tourism and any regional or global climate changes. Stocks of reef fish are stable or increasing in a few areas where fishing effort has declined (Bermuda, parts of the USA). Elsewhere, depletion of reef fish stocks range from relatively small (parts of the Bahamas, Turks and Caicos Islands), to severe (Haiti, Veracruz). Populations of the important, algal-grazing urchin, Diadema antillarum, remain small throughout the NAWC, and where there is severe nutrient pollution and/or intensive fishing, fleshy algae are abundant. Citizens in all NAWC nations are becoming aware of the ecological value and socioeconomic benefits of intact coastal ecosystems. Efforts to conserve and sustainably manage coral reefs are on the increase throughout the NAWC.

Introduction

The northern area of the wider Caribbean (NAWC) extends from the Dominican Republic and Bermuda on the east, to the Yucatan Peninsula and Veracruz coast of Mexico in the west. It includes three archipelagos with six nations (Bermuda; the Bahamas, and the Turks and Caicos Islands in the Bahamian Archipelago; and on the large islands, Cuba, and Dominican Republic and Haiti on Hispaniola), and two continental mainland countries (Mexico; United States of America). Reef types commonly include nearshore fringing reefs, shallow patch reefs, bank reefs or bank-barrier reefs along island or continental shelf margins, plus a few atoll-like structures. The cover of live reef corals is usually less than 40% of the bottom.

The NAWC is partially subtropical, and much of this area is also under the influence of the massive North American continent, therefore it spans a moderate range of environmental conditions. There are fewer coral species on the northern reefs, but some of the largest head corals (especially Montastraea spp.), and highest coral cover, are found at 15–20 m on the deep crests of the low diversity Flower Garden Banks in the northwestern Gulf of Mexico. There are only three species of Acropora in the wider Caribbean (compared with many species in the Indo-Pacific), but none of these are found in the more northerly areas (Bermuda; northern Gulf of Mexico; eastern USA north of Boca Raton, Florida). In other areas of the NAWC that are protected from high waves, the elkhorn coral Acropora palmata can dominate shallow reef zones, while the staghorn, A. cervicornis, may be prominent between 10–20 m. The fused staghorn (Acropora prolifera) is rare. However, an unfortunate development has occurred during the last 20 years, as numerous Acropora stands have lost much of their cover because of exposure to temperature extremes, white-band disease, and the direct or indirect effects of pollution. Dead colonies have been found in the 'relatively pristine' central-eastern Bahamas, Turks and Caicos Islands, and Cuba, on 'clearly perturbed' reefs of the Dominican Republic and Florida Keys, and on the 'highly impacted' reefs of southern Veracruz. Modest recolonization is occurring on many of these reefs.

The prevailing northeast trade winds do not routinely generate waves as large as those in the eastern Caribbean, but hurricanes are common throughout the NAWC, as are winter storms when large, polar fronts come down through North America. Average seasonal variations of surface seawater temperature range from about 4°C in the Dominican Republic and the Mexican Caribbean, to about 13.5°C (~15–28.5°C) in Bermuda. Unusually low temperatures have caused mortality of common corals (Acropora, Agaricia, Montastraea, Porites) on reefs in the northern Bahamas, northern Veracruz and southern Florida during severe winters (e.g. in 1970, 1977, 1981). Upwelling of cold, nutrient-rich waters may restrict offshore reef development along the northeastern Yucatan shelf, and may also affect coral reefs in the Bahamas, Cuba, Dominican Republic and USA.

Bleaching events are more likely to occur when sea-surface temperatures increase by as little as about 1°C above the long-term average for about a week in summer. As many as eight mass bleachings have occurred on some NAWC reefs since 1983; 1998 has been a major year for coral bleaching, at least in the Bahamas, Bermuda, Haiti, the Mexican Caribbean and Florida. Coral diseases are also more common during the warm summer months.

Populations of the long-spined urchin, (Diadema antillarum) died out suddenly throughout its entire range in the wider Caribbean during 1983–1984. Fleshy algae capable of smothering corals have subsequently proliferated in some areas of the NAWC, particularly where over-fishing has removed large-sized herbivorous fishes.

Human coastal population density varies from fairly low (2 to 63 per km^2 in Yucatan, Mexico; 20 to 30 per km^2 in the Bahamas, Turks and Caicos Islands) or moderate (250 per km^2 in the Florida Keys), to fairly high (up to 2200 per km^2) near major cities like Havana (Cuba), Santo Domingo (Dominican Republic) and Veracruz (Mexico). Tourists often outnumber local populations at popular coastal resorts: 7 to 1 in Puerto Plata (Dominican Republic), 8 to 1 in Cozumel (Mexico), 10 to 1 in Bermuda, 12 to 1 in the Bahamas, 38 to 1 in the Florida Keys, and 75 to 1 in Tulum (Mexico).

Watersheds in many of the continental and large insular parts of the NAWC were deforested so many decades ago that it is not now possible to estimate how freshwater and terrestrial soils naturally impacted coastal reefs. Nowadays, reefs located near some permanent settlements, tourist resorts, marinas, agricultural fields, and river mouths are suffering from the effects of excessive sediments, nutrients and, in several nations, pesticide pollutants. Chemical pollution (e.g. hydrocarbons, heavy metals), and/or physical damage from boat groundings, are characteristic impacts near large ports and cities.

Manatee (Trichechus manatus) and jewfish (Epinephelus itajara) are commercially extinct throughout the NAWC. Populations of queen conch (Strombus gigas) and/or spiny lobster (Panulirus argus) are greatly reduced in some areas. Fishing pressures have been so intense in Haiti and Veracruz that many of the edible fish and invertebrates caught by artisanal fishers are below sexual maturity.

STATUS OF CORAL REEFS

The Bahamas

The Bahamas cover a large area (260,000 km^2), with thousands of small patch reefs, dozens of narrow fringing reefs, and a few atoll-like and bank-barrier reefs. Reef development in much of the Bahamas is naturally limited by exposure to hurricanes (windward sites), by unusually cold winters (northern Bahamas) and by turbid, high salinity waters (leeward bank margins). Many Bahamian reefs are in fairly good condition, although white-band and other diseases have affected corals from San Salvador in the east to Andros in the west.

Edible reef animals are still common on many Bahamian reefs, but there is some local over-exploitation of whelk (Cittarum pica), queen conch, spiny lobster, and several species of grouper. Limited illicit fishing activities include use of toxic chemicals, harvesting of hawksbill turtles (Eretmochelys imbricata), undersized queen conch, and spiny lobster; in some areas spiny lobster are fished out of season or with prohibited diving gear. Artificial shelters are often positioned close to reefs where it is feared they may aggregate existing spiny lobsters, rather than enhance natural stocks. There is a legal harvest of adult green turtles (Chelonia mydas) during an open season (April–July). Sand is still being mined from a few reef sites on a fairly small scale.

There are four parks or reserves with coral reefs in the Bahamas, and eight other reef sites are informally protected (one of which is likely to be given formal protection under a new Fisheries Act which should be in force by the end of 1998.) Over half of the commercial dive sites have mooring buoys.

Bermuda

Fringing, bank-barrier and lagoonal patch reefs are found on the Bermuda Platform which, together with the nearby Challenger and Argus Banks, occupy a total area of about 900 km^2 in the Sargasso Sea. The warm waters of the Gulf Stream allow Bermuda to be the most northerly (32°20'N) coral reef in the Atlantic Ocean. The number of reef coral species is less than half of that in Florida (20 vs 48), yet the health of these small reefs is good overall. Grazing by parrotfishes (scarids) and surgeonfishes (acanthurids) was sufficient to prevent

even a temporary increase in the cover of fleshy algae after most of the Diadema died in 1983. However, the occasional grounding of large vessels and subsequent salvage operations have collectively destroyed about 1% of Bermuda's outer reefs since 1940. Queen conch are also commercially extinct.

Bermuda is remarkable for its high priority on conservation, despite supporting one of the largest human population densities on earth (over 1000 per km^2). A high level of protection for about a quarter of the Bermudian coral reefs is provided in two coral reef preserves, three seasonally protected no-take fishing areas and nine very large protected dive sites. Recreational fishers have bag limits, and commercial trap fishing for finfish was totally banned in 1990. Recently the number of convictions for use of illegal fish traps has increased in Bermuda.

Cuba

Numerous fringing and bank-barrier reefs border much of Cuba's 3200 km-long shelf margin, although over 50% are separated from the mainland by cays or by broad, shallow lagoons that contain many patch reefs. Most of the Cuban reefs are in relatively good condition, excepting those near large population and industrial centres (along less than 3% of the shoreline), where the seawater is conspicuously polluted. There has been some localized death of Acropora from white-band disease. Sediment in runoff may affect some nearshore reefs along 30% of the mainland coast. Increases in large, fleshy algae on some offshore reefs since the die-off of Diadema antillarum are probably related to high concentrations of phosphate in effluents from the sugar industry and other wastewaters.

Stocks of most reef fishes in Cuba are in comparatively good condition (larger fish sizes, high biomass), and artificial shelters for spiny lobsters have been used sustainably for several decades. However, Nassau grouper (Epinephalus striatus) and sharks are overfished. There is limited, illegal harvesting of several species of gorgonians, black coral, spiny lobster, and turtles.

There are no marine protected areas in Cuba, but tourist operators are informally protecting the reefs near some resorts. Only a few commercial dive sites have mooring buoys. In 1997, anchoring, erecting structures, dredging, dumping sediments and solid wastes, using explosives, and unauthorized collection of all corals, were prohibited by a joint resolution of the Ministries of Fisheries Industry and of Science, Technology and Environment.

Dominican Republic

Fringing reefs, and small barrier reefs are scattered along less than 170 km of the coastline of the Dominican Republic, with some offshore bank reefs. Many coastal reefs are in fairly poor condition, and may have been damaged by anthropogenic increases in sediments (due to upland deforestation, wetland removal, soil erosion, and coastal construction), nutrients (from fertilizers as well as domestic wastewaters) and pesticides (in agricultural runoff). Large, fleshy algae have proliferated at the expense of reef corals at many localities, including an underwater park (La Caleta). Coral reefs have clearly declined near polluted coastal cities (Santo Domingo; Haina). Small-scale breakage of corals by snorkellers and SCUBA divers is conspicuous at numerous dive sites, particularly near the most popular tourist centres on the north and east coasts.

Artisanal fishing has been reduced within the last decade, and reef fish populations are increasing. Nevertheless, queen conch, spiny lobster, groupers, snappers, grunts, aquarium reef fish, black corals, hermit crabs, and 'live rock' are still intensively harvested (both in and out of legal seasons) in some parts of the Dominican Republic. Illegal collection of loggerhead, hawksbill, and green sea turtles is on the decline.

Approximately 20% of the coral reefs in the Dominican Republic occur within marine parks and sanctuaries. Efforts to both monitor and manage these protected areas have been initiated. About a quarter of the commercial dive sites have mooring buoys.

Haiti

Little is known about the barrier, fringing, and patch reefs that skirt the coastline of Haiti and its offshore islands. Soil erosion and wetland removal are particularly severe (perhaps less than 1% of the native vegetation remains intact). There are no sewage treatment plants, nor sanitary landfills in this nation of 8 million people. Nutrient pollution has contributed to the growth of fleshy algae that are smothering corals on reefs near Port-au-Prince and Cap Haitian. Port-au-Prince is also severely polluted with oil, industrial chemicals, and trash. Although fishing permits are required by law, the number of active fishing boats greatly exceeds the number with permits, and fishing is so intense that few fish reach reproductive size. There are no marine protected areas in Haiti, although one is planned, and none of the commercial diving sites have mooring buoys (although these are being planned).

Mexico (Veracruz)

The 29 small, platform-type reefs in the southwestern Gulf of Mexico are among the most stressed by both nature and humans in the entire Caribbean. Corals on reefs near the coast are sometimes killed by low winter temperatures or by runoff during the rainy season. Cold-

induced mass bleaching of head corals (Colpophyllia, Diploria, Montastraea) has occurred as recently as December, 1994. Anthropogenic increases in sediments and nutrients, plus agricultural and industrial chemical pollution, have probably contributed to the disappearance of many corals within the last 20–30 years, and to their replacement by fleshy algae, particularly in the shallow (3–5 m) zones of the nearshore, southern Veracruz reefs. Coral skeletons contain relatively high concentrations of heavy metals, particularly on reefs near the port of Veracruz.

Queen conch are commercially extinct, and reef corals, black corals, seashells and other curios, spiny lobsters, sea-urchins, along with many edible and non-edible fish and sea turtles are over-harvested (often illegally) on the Veracruz reefs. Reef coral skeletons were extensively used in the construction of public buildings and a fort during the 17th and 18th centuries. Large-scale physical damage includes boat groundings, military manoeuvres, and the construction of the Veracruz harbour; at a much smaller scale, corals are smashed by recreational snorkellers and SCUBA divers. Over 70% of the Veracruz reefs are contained within a marine park, although levels of management and enforcement are minimal.

Mexico (Yucatan)

The Yucatan Penninsula contains narrow barrier and fringing reefs on the eastern (Caribbean) coast, and fringing reefs around offshore islands in the southeastern Gulf of Mexico (its western flank). There are also several atoll-like structures on offshore banks (Alacran on Campeche Bank, Chinchorro). Limited upwelling of cold, nutrient-rich water may naturally restrict reef development on the northeastern margin of Campeche Bank.

Coastal development is expanding so rapidly along much of Mexico's Caribbean coastline, and with such little consideration of existing regulations that, with the possible exception of the Sian Ka'an Biosphere Reserve, the continued integrity of these coastal resources is seriously threatened. Nearshore water quality is particularly poor near some major tourist resorts. Reefs near the petroleum industry's platforms in the southeastern Gulf of Mexico are routinely exposed to small hydrocarbon spills. Black coral, queen conch, other invertebrates, fish, and sea turtles are collected illegally in the Yucatan. Large-sized algal grazing fishes have been over-harvested on some reefs, and fleshy algae capable of overgrowing reef corals may be increasing in cover.

About a third of the Yucatan's coral reefs are located within seven marine parks, reserves, and protection zones, but there is little effective management. Local residents are providing informal protection at several dive sites. Artificial shelters for spiny lobsters have been deployed sustainably in a large bay for several decades.

Turks and Caicos Islands

At the southeastern extension of the Bahamian archipelago, the windward fringing reefs of the Turks and Caicos Islands are exposed directly to the open waves of the Atlantic Ocean. Water quality is generally very good, as there is no major agriculture apart from small market gardens, and no major industry other than a small brewery, and a factory to make drinking water. The ten large hotels are all based on one island, and most have their own desalination and sewage treatment facilities.

Queen conch and spiny lobster are fully exploited, mostly for export, and some of the latter are caught illegally with bleach. Most reef fish are harvested sustainably. Three snorkel trails were established in 1997 to reduce diver damage to popular patch reefs, and for public outreach education. Dive operators also brief tourists in correct 'reef etiquette'. The three marine national parks have well-maintained mooring buoys for dive boats, however, management strategies are still being determined. Dropping anchor within the marine parks is a punishable offence and there have been some successful prosecutions.

Florida Reef Tract (USA)

There are a few dozen bank-barrier reefs, and thousands of lagoonal patch reefs, off the southeastern coast of Florida and the islands of the Florida Keys; further southwest is the atoll-like Dry Tortugas reef. This 320 km-long reef tract is influenced by the clear Florida Current (Gulf Stream) and by the turbid waters of Florida Bay, which can be either warm and of high salinity or cold and, sometimes, of low salinity. Few reefs have developed opposite the wide tidal passes located in the middle region of the Keys, and some reef corals die during severe winters (most recently in 1981).

Water quality has markedly deteriorated in the Keys over the last 30 years. Changes of water flow patterns in Florida Bay (due to the causeways connecting the islands to the mainland), increases in sedimentation (from recreational boat traffic, dredging, historical infilling, and wetland removal), and of nearshore nutrient concentrations (from local wastewaters, and fertilizers from the agricultural fields of southern Florida), plus industrial pollutants from Miami, have probably all contributed to this decline. Live coral cover has significantly decreased on some bank-barrier reefs. White-band and other coral diseases have been obvious for over 20 years, as have mats of sediment-trapping turf algae that gradually encroach over reef corals and restrict the settlement of new recruits. The large amount of boat traffic results in major damage to shallow reefs and seagrass beds from propellor scrapes (especially of recreational boats) and groundings (commercial vessels in particular). Queen conch and Nassau groupers are commercially extinct, spiny lobsters are fully exploited, and many species of groupers and snappers are also over-collected.

The entire Florida reef tract is under some form of state or federal management. Mangroves are expanding on artificial islands (dredge spoils). Shipping lanes are better defined, and the heavy fines imposed after major groundings are being used to salvage corals, repair reef foundations, and for follow-up research and monitoring. There are mooring buoys at all commercial diving sites. Pump-out facilities are being installed at public marinas and docks. To date, fishing is restricted in only 0.5% of the Florida Keys National Marine, however, planning is under way to declare larger areas of the Dry Tortugas as a fishing reserve. Queen conch populations are being re-stocked with captive-bred juveniles.

Flower Garden Banks (USA)

The East and West Flower Garden Bank reefs, which cover less than 90 km^2, are located 200 km south of the Texas/Louisiana border. Naturally protected by their remoteness from the mainland and by their depth; even hurricanes inflict relatively little damage to the head corals that predominate on the 15–20 m deep bank crests. Water temperatures are neither as warm nor as cold as sometimes happens at comparable latitudes in Florida and the Bahamas.

Live coral cover has been relatively high (about 45% on the bank crests) since monitoring first began in 1972, and coral diseases are rare. There was a rapid expansion of fleshy algae in 1984 after the sea urchin, Didema antillarum, died off, but this was reversed within a year, apparently after the populations of large, herbivorous parrotfishes (stoplight, Sparisoma viride and Queen, Scarus vetula) increased.

Strong regulations have meant that there has been remarkably little impact from the petroleum industry, although there are about 4000 hydrocarbon production facilities and over 35,000 km of pipelines in the northwestern Gulf of Mexico. Harvesting of reef organisms was restricted to hook-and-line fishing, anchoring by commercial vessels was prohibited, and mooring buoys for dive boats were installed, when the Flower Garden Banks became a National Marine Sanctuary in 1992.

Management of coral reefs

Tourism has brought considerable economic benefits to many nations in the NAWC, but the coastal reefs that attract many of these visitors are often stressed by sediment and nutrient pollution, and by over-harvesting of reef resources. There is increasing awareness of the perils of unrestrained population and economic growth on societies and the environment. Many individuals, NGOs, foundations, industries, financial, and academic institutions, and even governments, are collaborating to conserve or restore coastal habitats, in part because they recognise the major benefits that derive from reef-based tourism. Most NAWC nations have some

form of environmental legislation, but enforcement is particularly poor in Haiti and Mexico. Government commitment to international treaties like MARPOL, CITES, and the Convention of Biological Diversity has enhanced compliance with local environmental, fishery and development regulations in the Turks and Caicos Islands, Cuba, and the Dominican Republic.

Concepts of integrated coastal (or catchment) management are just beginning to be applied in this area. The Global Environmental Fund (GEF) of the World Bank is funding a Cuban project to protect biodiversity and establish responsible coastal tourism development in the Sabana-Camaguey ecosystem. Mexico has joined with three nearby Central American countries in the Meso-American Caribbean Coral Reef System Initiative, which is a regional approach to reef conservation and sustainable management supported by the World Bank. After extensive input from a citizens Sanctuary Advisory Council, the multiple-use, integrated coastal management plan for the Florida Keys National Marine Sanctuary was adopted in 1997.

Shoreline development is closely controlled in Bermuda; comparable projects in the Turks and Caicos and in Cuba are restricted to the landward side of beach dunes. Turbidity barriers, or some other method of sediment control, are required at coastal construction sites in Florida, and are sometimes used in the Mexican Caribbean.

Artificial wetlands and composting toilets are helping to remove nutrients from wastewater in several coastal villages along the Mexican Caribbean. Methods of removing nutrients from wastewater are presently being tested in the Florida Keys, and the Key West ocean outfall is being discontinued as part of legislation banning the discharge of raw sewage into US navigable waters. Live-aboard boats must also comply, and pump-out facilities are being installed along the coastlines of Florida and Texas.

Mooring buoys have been installed at nearly all commercial dive sites in the Turks and Caicos Islands and in the USA, and are being placed elsewhere in the NAWC. Anchoring by commercial vessels has been banned on the Flower Garden Banks, and boat groundings on the Florida Keys have been greatly reduced, since both were designated as National Marine Sanctuaries.

There are laws against collecting hard corals in most NAWC countries, and there are no recent reports of fishing with explosives. The use of poisons to capture aquarium or edible fishes has greatly declined. Reef fish populations are increasing in some areas where market pressures have reduced the numbers of active fishers (Dominican Republic), or where fishing regulations are enforced (Bermuda, Cuba, some reefs in the USA). Queen conch and spiny lobster fisheries are locally sustainable in some NAWC nations. Alternatives to fishing on coral reefs include artificial reefs in Cuba, Mexico, and the USA, and fish aggregating

devices in the Dominican Republic and Mexico. Queen conch populations are being stocked with captive-bred juveniles in Florida.

Although steady progress is being made by NGOs and government agencies at funding and training personnel (especially in Bermuda and the USA), at this time only a few of the NAWC's marine protected areas are adequately monitored or effectively managed. Nonetheless, the GEF is supporting the development of coral reef monitoring protocols in the Bahamas (some of which will be conducted in protected areas), as well as ecological assays and biodiversity inventories at four marine parks in the Dominican Republic. Mexico has formed a multi-disciplinary and broadly representative scientific and technical advisory committee (Comite Cunsultor Cientifico y Tecnico de los Arrecifes Coralinos — COCCYTAC) to advise government on improved monitoring and management of Mexican MPAs as part of their commitment to the International Coral Reef Initiative and the Global Coral Reef Monitoring Network. Some of the supposedly protected areas in the Bahamas, Turks and Caicos Islands, Dominican Republic, parts of southern Yucatan, as well as many unprotected areas in Cuba, are sufficiently remote from large human populations as to be relatively unaffected by direct human activities, excepting periodic over-fishing. Ever larger numbers of divers are helping to protect reef resources from illegal fishing, clean up trash, conduct reef monitoring surveys, and educate others about the value of intact reef ecosystems.

Conclusions

Research is needed to determine the long-term consequences of coral diseases and mass bleaching (since 1987) on some NAWC reefs, and whether these phenomena are linked to local or regional anthropogenic stresses. Populations of Diadema antllarum have not recovered since the 1983–1984 mortality event, and fleshy algae are overgrowing reef corals in some areas of the NAWC, particularly where intensive fishing has removed algal-grazing fish. Within the last 20 to 30 years, reef corals have clearly declined near major sources of pollution (Havana, Santo Domingo, Veracruz) and in the Florida Keys.

Stewardship of coral reefs within the NAWC's marine protected areas varies from essentially nil (Mexico) to good (Bermuda, Flower Garden Banks). Apart from over-harvesting, direct human impacts on the remote reefs of the Bahamas, Turks and Caicos Islands, Cuba, and the Flower Garden Banks are comparatively low. With the possible exception of the Sian Ka'an Biosphere Reserve, most of the Caribbean reefs of Mexico are threatened by an explosive growth in tourism; elsewhere pressures from fishing or recreational diving range locally from modest to excessive.

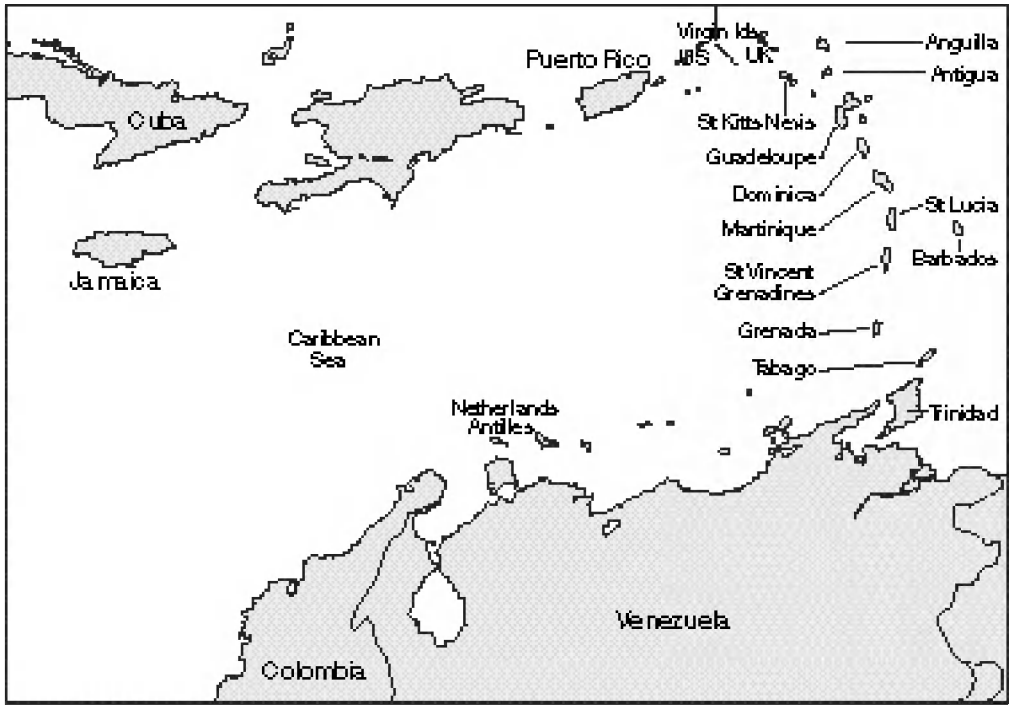
The authors come from institutions throughout the western Atlantic: Judy Lang, University of Texas at Austin, USA; Pedro Alcolado, Instituto de Oceanología, Habana, Cuba; Juan Pablo Carricart-Ganivet, Departamento de Ecología Acuática, Chetumal, México; Mark Chiappone, The Nature Conservancy, Miami, USA; Al Curran, Smith College, Northampton, Massachusetts, USA; Phil Dustan, University of Charleston, USA; Gudrun Gaudian, Department of Environment and Coastal Resources, Grand Turk, Turk and Caicos Islands; Francisco Geraldes, Universidad Autónoma de Santo Domingo, Republica Dominicana; Steve Gittings, National Oceanic and Atmospheric Administration, Rockville, Maryland, USA; Robbie Smith, Bermuda Biological Station for Research; Wes Tunnell, Texas A&M University-Corpus Christi, USA; Jean Wiener, Fondation pour la Protection de la Biodiversité Marine, Port-au-Prince, Haiti.

9. Status of coral reefs in the Lesser Antilles, western Atlantic

Allan Smith, Caroline Rogers and Claude Bouchon

Abstract

The Lesser Antilles include high volcanic islands with very narrow continental shelves, and some low coral islands with wider shelves. There are some excellent coral reefs, which are normally impacted by rainfall and runoff, and hurricanes. Recently, coral bleaching, coral diseases, tourism, and fishing pressure have resulted in some degradation in many areas, but there are few long-term studies to determine the status of the reefs, and the trends. There has been an increase in the number of reefs under active and effective management, and the need for better management is being recognised.



INTRODUCTION

There has been progressive degradation of reefs in the Lesser Antilles over the past 10 to 20 years. But there is also growing recognition of the economic and ecological value of reefs, and increasing monitoring and management of coral reefs. Many of the reefs now have less live coral cover, fewer and smaller fish, and more algae than before, because of both human and natural impacts. Recent hurricanes have been very damaging (Hurricane Gilbert in 1988; Hugo in 1989; Luis and Marilyn in 1995), and also coral diseases have caused a lot of coral death. The impacts of Hurricane Georges (September 1998) are yet to be assessed.

Over 40 species of hard corals have been found on the United States Virgin Islands reefs, but the primary reef-building coral in the shallow water of many reefs, Acropora palmata, has been severely affected by white-band disease and shows little recovery. Any new colonies have been destroyed by major storms, along with much of the other major reef-builder, Montastrea annularis. There have been several episodes of coral bleaching, probably associated with above normal water temperatures, which have caused partial mortality of many species. The massive die-off of the long-spined sea-urchin, Diadema antillarum, in 1983, and over-fishing, have resulted in dramatic increases in macroalgae, which are smothering coral colonies and reducing coral recruitment and survival. On the steep-sided islands, there has been heavy runoff of sediments and nutrients onto the reefs because increased populations are clearing the hillsides.

Tourism has expanded rapidly in the region with more cruise ships, new docks, marinas, and hotels, along with more dredging, and filling of coastal areas. Diving tourism is developing rapidly, and there are worries that the carrying capacity of these small reef areas has been exceeded already.

STATUS OF REEFS AND THEIR MANAGEMENT

United States Virgin Islands

Over 40 coral species occur on the United States Virgin Islands reefs of St. Thomas, St. John, and St. Croix. Most of the reefs are shallow fringing reefs, parallel to the coast, or corals growing on submerged boulders and rocky ridges near the shore. There are the same pressures as on other Caribbean reefs: four hurricanes and many other major storms in the last 15 years; higher than normal water temperatures; coral diseases; destruction from boat anchors and boat groundings; careless land use; dredging; pollution; and over-fishing. All these cause reef deterioration. In the last 15 to 20 years, live coral cover has

declined while the algae have increased, because there are few herbivorous fish and sea-urchins to control them.

The biggest recent change on the United States Virgin Islands has been the virtual loss of the elkhorn coral, Acropora palmata, due to white-band disease and Hurricanes David (1979), Frederic (1979), and Hugo (1989), which have reduced cover at some sites from 85% to as little as 5%. In 1987, 50 A. palmata colonies in Hawksnest Bay on the north of St. John were reduced to only 10 after seven months because of heavy seas and damage from snorkellers and boats. Coral cover around St. John and Buck Island was less than 30%, but dropped to between 8% and 18% following Hurricane Hugo (1989). The dominant coral, Montastrea annularis, declined by about 35% in Lameshur Bay, and there has been no substantial recovery, although coral recruitment is occurring. Decline in M. annularis is a concern because this is now the major reef-building species in the Caribbean. In 1995, reefs off Buck Island (St. Croix) and St. John were severely damaged by boats, which broke loose and dragged across the corals.

The next biggest threat to the United States Virgin Islands reefs is sediment runoff from coastal developments. A special problem is construction of new roads and development of private land inside and near the parks. Some black-band disease has been reported on Montastrea annularis and Diploria strigosa around St. John and at Buck Island Reef National Monument.

National parks are a 'mixed blessing', for example the Virgin Islands National Park attracts one million visitors a year, mostly on cruise ships or smaller boats. But a single anchor drop from a cruise ship in 1988 destroyed 300 m^2 of reef, with no significant recovery eight years later. Mooring buoys were installed after it was shown that about 33% of boats were anchored in seagrass beds, and 14% on the corals. Unfortunately, there is little coral left to protect with these measures, and no limits on the size of vessels allowed in park waters.

British Virgin Islands

Tourism has expanded considerably in the British Virgin Islands (Tortola, Virgin, Gorda, Anegada, Jost van Dyke, and approximately 40 smaller islands and cays). Yacht charter and recreational boating, cruise ships, and diving tourism are particularly important to the British Virgin Islands economy. But development for this has resulted in coastal degradation, increased sedimentation, land reclamation, dredging and construction, and sewage pollution. And there has been damage to corals at dive sites from anchors, and from the large numbers of novice divers. Hurricanes Hugo (1989), and Luis and Marilyn (1995), badly damaged corals, particularly shallow-water Acropora palmata.

There are three marine protected areas, and Baths National Park and the Wreck of the Rhone Marine Park include coral reef areas. The National Parks Trust and the Dive Operators Association collaborated to put in permanent moorings to reduce boat anchor damage at heavily-used sites, and to generate revenue for management. Horseshoe Reef MPA, near Anegada, is managed by the government's Conservation and Fisheries Department, which limits diving and fishing.

Anguilla

In 1993, five marine parks were established, with four protecting coral reefs (Sandy Island, Prickly Pear-Seal Island reefs, Island Harbour, and Dog Island Marine Parks, managed by the Department of Fisheries). Tourism development has had little impact, because most reefs are a long way offshore, but the many visitors result in anchor damage and breakage of shallow corals by snorkellers. The Dog Island reefs are almost pristine, and park managers discourage visitors in order to maintain one area intact, for comparison with the tourist areas. Anguilla has not been hit by a hurricane since 1960, but big waves from Hurricane Luis in 1995 caused extensive damage to Acropora palmata in shallow water.

The Netherlands Antilles

The Windward island of St. Eustatius has steep cliffs with little shoreline development (except an oil trans-shipment port) followed by a flat sandy plain with little coral growth. Hurricanes Luis and Marilyn (1995) removed large amounts of sediment from the eroding cliffs and severely damaged soft corals and sponges, but recovery was rapid. The Statia Marine Park was established in 1996 and managed by the St. Eustatius National Parks Foundation to protect two sections of reef along the coast.

The Windward island of Saba is very steep, which limits coastal development, and human impacts are minimal. There was little damage by Hurricanes Luis and Marilyn (1995). This is a popular diving destination and all reefs down to 60 m are protected in the Saba Marine Park, established in 1987 and run by an nongovernmental organisation, the Saba Conservation Foundation. There is active management by permanent staff, financed by income from tourism since 1993. No adverse effects have been observed from tourism, but there is a need for studies on carrying capacity to prevent damage from over use.

St. Maarten is a Windward island shared between the Dutch (southern portion) and the French Antilles. The south and west coast reefs are seriously threatened by pollution, devegetation, siltation, and eutrophication from sewage, and much recreational boating and anchor damage. There has been major development following rapid population growth and a dramatic expansion of tourism, but there is no planning strategy and there are no protected areas. Heavy seas from Hurricane Luis damaged reefs, seagrass beds and beaches, and resuspended sand

smothered Acropora palmata stands in shallow water, but these have largely recovered. The island government is determining conservation priorities, and is planning a marine park.

The French West Indies

The French West Indies comprise the islands of Martinique, the Guadeloupe Archipelago (with Guadeloupe, La Désirade, Marie-Galante and the Les Saintes islands), St. Barthélémy, and part of St. Martin. Reefs are absent on the leeward side (northwest and west) of Martinique, because the shelf is narrow and there is sediment from the erosion of Montagne Pelée. There is some healthy coral growth in patches. The northern coast has little coral growth because of its steepness and high sedimentation. Further south, fringing reefs have developed along the coast protected by a barrier reef.

Guadeloupe has two islands: Basse-Terre is high and volcanic; and Grande-Terre is flat and calcareous. The Caribbean coast of Guadeloupe has the most diversified coral communities on the rocks, but there are no reefs because the shelf is narrow and sedimentation is high. There are fringing reefs on the Atlantic side of the other islands (La Désirade, Marie-Galante and Les Saintes Archipelago). Likewise, there is limited coral reef development around the islands of St. Barthélémy and St. Martin. Hurricane Georges passed directly over Guadeloupe in September 1998.

The coral reefs of Martinique were damaged by swells from Hurricanes David (1979) and Allen (1980), with large losses to Acropora palmata and A. cervicornis communities on shallow outer reef slopes. Guadeloupe was hit by Hurricanes Hugo (1989), which damaged branching corals of the shallow fore-reef zone, and Luis and Marilyn (1995), which smashed corals, sponges and gorgonians down to 25 m and resulted in much sedimentation on the reefs. Hurricane Luis caused some damage to coral reef communities of St. Martin and St. Barthélémy, and generated a large amount of fine calcareous sand that was suspended for months and killed many animals that had survived the hurricane.

Massive coral bleaching has never been seen in the French West Indies, but there is chronic bleaching every year in September, when water temperatures reach 29°C. The brown alga Sargassum invaded the Caribbean coast of Martinique in 1984 and was still present in 1996. The most probable cause is eutrophication from the city of Fort-de-France. There is proliferation of brown algae (Sargassum, Turbinaria and Dictyota) on the reefs of Martinique, Guadeloupe, St. Martin, and St. Barthélémy. The Pigeon Islets (leeward side of Guadeloupe) are one of the most famous SCUBA diving spots, but there is evident physical damage from 80,000 divers per year. There is some protection with a ban on most fishing activities, and the installation of permanent moorings.

The Grand Cul-de-Sac Marin marine reserve, created in 1987 and managed by the Parc National de la Guadeloupe, is also a Man in the Biosphere Reserve, and includes coral reefs, seagrass beds, and mangroves. The ongoing project to establish a marine reserve in the Baie-du-Trésor, Martinique, has not been completed. There are also two marine reserve projects for the islets of Pigeon and of Petites-Terres on the Atlantic coast of the Guadeloupe. A marine reserve was created on St. Barthélémy, in 1996, and there is an ongoing project for one on St. Martin.

St. Kitts and Nevis

The reefs now have lower species diversity than similar areas in the region, probably because of sedimentation, but are becoming increasingly important for diving tourists. Marine conservation is focussed on the low and dry Southeast Peninsula of St. Kitts, and on deeper reefs off the west coast, which have higher diversity and cover of coral than other reefs. The proposed Southeast Peninsula Marine and Recreation Park has been declared and there are fears that clearing of land will increase sedimentation on the reefs.

Montserrat

Corals occur as scattered patch reefs from 2 m to 40 m off the west and north coasts. Runoff and steep slopes limit the distribution of reefs around the island, particularly near ravines that carry sediments. Large-scale, and ongoing volcanic eruptions are damaging reefs on the south and southwest coasts. Additionally, there has been damage from Hurricanes Hugo (1989) and Luis (1995).

There are low human impacts from pollution and diving tourism, and the reefs were relatively pristine, with high diversity. Trap and spear fishing are potentially destructive, given the limited amount of reef. No marine protection can be contemplated as the volcanic activity has disrupted government.

Antigua and Barbuda

These are coral limestone islands. Antigua is deeply indented and surrounded by reefs, except on parts of the west and south coasts. Reefs are found along most of the coast of Barbuda, with an extensive algal ridge on the east coast. The reefs are under stress from sedimentation from shoreline tourism development, and destruction of wetlands. Hurricanes Hugo (1989), and Luis and Marilyn (1995), caused extensive damage to reefs on the south and southeast coasts of Antigua, particularly to branching corals on shallow reefs.

The Palaster Reef Marine Park on Barbuda, and the Diamond Reef Marine Park on Antigua were legally established in 1973, but management has not yet been implemented. Great

Bird Island will be declared as a protected area after a participatory planning and implementation process.

Dominica

Reef development is limited on the narrow coastal shelf. But on the south, west, and northwest coasts, corals grow on rocks and on the steep slopes and walls, making spectacular dive sites for the increasing numbers of diving tourists. The small population and minimal coastal development means that the corals are not severely impacted by human activities. No hurricanes have hit since Hurricane David in 1979, however, Hurricane Luis in 1995 caused heavy sedimentation and wave destruction of Porites sp. along the southwest coast.

The Soufriere Scott's Head Marine Reserve on the southwest coast is about to be legally established, and management has begun the installation of permanent moorings through collaboration between the government and divers.

St. Lucia

There are narrow fringing reefs and coral veneers all along the volcanic island coast, with some small patch reefs in the southeast. The spectacular reefs along the west coast are very important for fisheries and diving. Storms have been the major natural disturbance. Tropical Storm Debbie in 1994 was very wet and resulted in heavy sedimentation from runoff, which caused coral mortality as high as 50% near river mouths. In 1995, waves from Hurricanes Luis and Marilyn caused severe damage to shallow stands of Porites sp. on the west coast.

These narrow fringing reefs are under high pressures from the concentration of population along the coast. Tourism and urban development on the west coast around Soufriere have resulted in conflicts between user groups, for example between fishers and divers over reef use, and between fishers and yachts anchoring in fishing zones. Marine reserves and fishing priority areas were established in 1986 and a management plan proposed, but there was no input from the users, and conflicts escalated. Conflict resolution and participatory planning was initiated in 1992 by the Soufriere Regional Development Foundation, a local NGO. After 18 months of negotiation, all institutions and users agreed to the establishment of the Soufriere Marine Management Area. This was endorsed by government, and officially launched in 1995. Management is under the supervision of a Technical Advisory Committee, which includes fishers, hotel and dive operators, community institutions, and relevant government agencies.

Barbados

The island is densely populated with extensive and expanding coastal development, and tourism. Eutrophication, from development on the west coast, has resulted in increased algal abundance, reduced coral recruitment and survival of juveniles, and increased turbidity and sedimentation. The reef flats were once covered by luxurious growth of elkhorn coral (Acropora palmata) but this disappeared soon after intensive sugar-cane growing started over a hundred years ago. On the offshore reefs, coral diversity dropped by 24% between 1982 and 1992, along with a 34% drop in abundance, and the amount of dead coral surface increased from 22% to 43% over 20 years. The government's Coastal Zone Management Unit established monitoring sites in 1987, where monitoring will be repeated every five years to ensure good information for management.

The only marine protected area is the Barbados Marine Reserve at Folkstone, on the west coast, and a marine park is planned for Carlisle Bay, with the possibility of management by the Professional Association of Dive Operators, in collaboration with the government.

St. Vincent and the Grenadines

The shelf around St. Vincent is narrow, with few reefs on the north and east coasts, but good coral grows on the rocks around headlands on the west coast. There are some fringing reefs on the south and southeast coasts. Reef growth is much better on the shelves around the Grenadine Islands to the south, and this is important for fishing and tourism. The Tobago Cays are particularly important, but the condition of the Tobago reefs has deteriorated over the past 15 years due to storm damage, white-band and other diseases, physical damage from fishing gear and boat anchors, and localized pollution from visiting yachts. An action plan to establish the Tobago Cays Marine Park was approved by government, and consultation with resource users has begun. Permanent moorings have been installed to reduce anchor damage by the many visiting yachts.

Grenada

Tourism development is very intensive on the southeast coast, particularly Grande Anse Bay. A sewage treatment system was installed following reports that nearshore reefs had fewer coral species and more abundant benthic algae, characteristics of nutrient pollution. There are no reports of damage from hurricanes. Reefs on the west coast of Grenada, and in the Grenada Grenadines, are very important for recreational diving, and a system of marine parks has been proposed by the Fisheries Department of the Government of Grenada, but not legislated.

Conclusions

There is a trend of increasing reef degradation in the Lesser Antilles during the last ten years. Human causes include many impacts from coastal development (increased sedimentation, nutrient enrichment, dredging and construction, and clearing of vegetation), and there have also been impacts from more severe and frequent storms and hurricanes, and more coral diseases.

There are large differences in the region in the knowledge and understanding of the need for reef conservation, and in the capacity to establish management and assess the status and trends of reef condition for management. The challenges are formidable, but there have been encouraging advances in reef protection and management. A positive sign is the increasing awareness of the ecological and economic value of coral reefs. Several new parks or management areas have been established and are providing valuable lessons for the region. In Saba and the British Virgin Islands, revenue from user fees makes a major contribution towards ensuring continuity in management, and avoiding the inconsistencies in funding that have hindered progress elsewhere. Low public support for management was a major drawback in the past, so the recent trend towards participatory planning, conflict resolution, and collaborative management is significant. In St. Lucia, collaboration between government, NGOs, and community groups has resulted in constructive and dynamic management, where previously there had been continuous conflicts and inadequate management. Inability to enforce protective legislation was a major hindrance to management, and improved public participation and support are the most effective means of reducing the need for enforcement, especially when human and financial resources are limited. The collaboration of the users also reduces the cost and improves management efficiency. Good examples are the involvement of diving groups in establishing mooring buoys around many islands, including Barbados and Dominica.

There is much to be learned from those islands that have developed effective coastal zone management programmes that are conserving the resources. Many of these programmes provide research and monitoring data on the effects of stresses to improve management in the face of increasing pressures on reef resources.

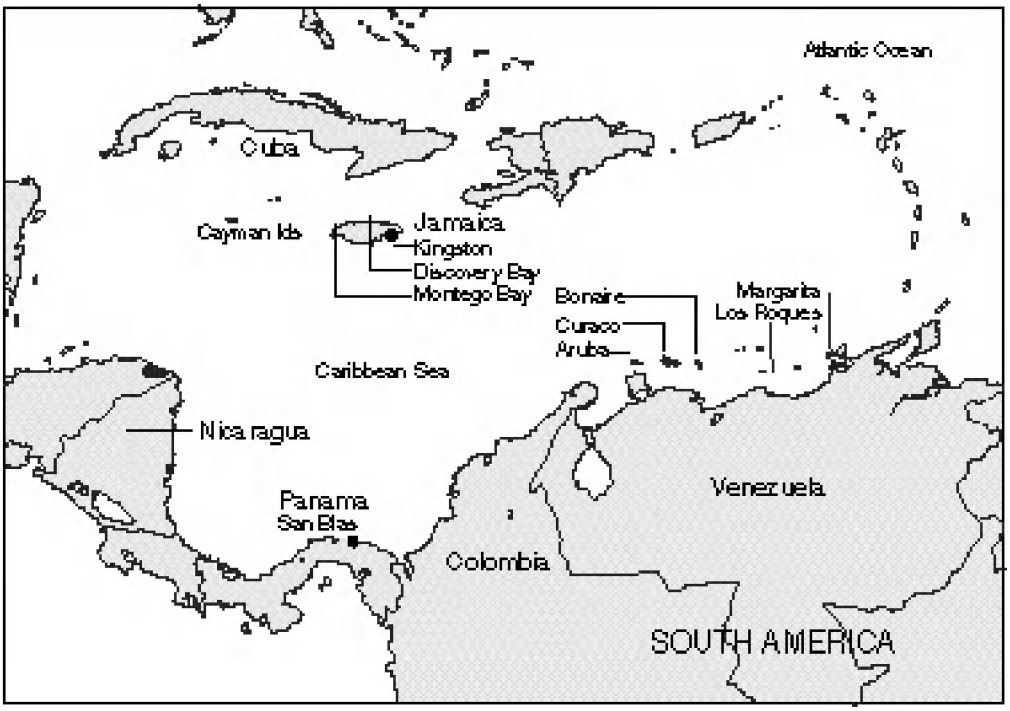
Allan Smith is at the Caribbean Natural Resources Institute on St. Lucia; Caroline Rogers is at the Virgin Islands National Park on St. John; and Claude Bouchon works from the Université Antilles-Guyane, Guadeloupe.

10. Status of coral reefs in the south-central Caribbean

Jeremy Woodley, Kalli De Meyer, Philippe Bush, Gina Ebanks-Petrie, Jaime Garzon-Ferreira, Eduardo Klein, Leendert Pors and Cornelius Wilson

Abstract

Caribbean corals have suffered from bleaching, diseases, and Diadema die-off. Reefs on narrow shelves adjacent to large human populations with many fishers (Colombia, Curacao, Jamaica, Venezuela) suffer from runoff of sediment and pollutants, over-fishing, and now show signs of degradation (fewer fish, more algae, less coral cover). Where shelves or banks are wide, or far from human populations, reefs are less disturbed. Islands with fewer people and little fishing pressure (Bonaire, Cayman) have good reefs. Here, diving tourism is economically important, and there is greater awareness of reef conservation. Cayman has the best-developed national coastal area management plan, while most other countries



have marine protected areas. These are stimulating improved coastal management, aided by increasing numbers of nongovernmental organisations (NGOs).

Introduction

Coral reefs have been degraded in all the six countries: Aruba; Netherlands Antilles (Bonaire and Curacao); Cayman; Jamaica; and reefs off the mainland of South America; Colombia; and Venezuela. Reefs on Bonaire and Cayman are in the best condition, while those showing the greatest damage are on the north coast of Jamaica, and at Moroccoy, Venezuela. Both natural and human impacts are implicated, often compounding each other, in all countries.

Hurricanes make the largest natural impacts on coral reefs. Their effects are greater in the northern Caribbean and are relatively rare off the South American mainland. They are often triggers for other major changes, because chronic human disturbances have altered the natural conditions and prevented normal recovery. Diseases are important (apparently natural) factors. Acropora corals, the dominant reef-builders in the Caribbean, have suffered high mortality from white-band disease. The large populations of the grazing sea-urchin, Diadema antillarum, have not recovered from the mass mortality in 1983, which resulted in massive increases in the amount of large algae in many areas.

Human impacts have greatly increased as populations and development expanded, and have resulted in more sediment and nutrient pollution, and over-fishing. The impacts are greatest near cities, towns, and villages, and on reefs on narrow shelves near large populations (like north Jamaica). Where shelf and reef areas are larger (south coast of Jamaica, Caymans), reef fish are larger and more abundant, and help prevent algal overgrowth.

Status of coral reefs

Aruba

Aruba is a small island (32 km by 10 km) off Venezuela, with considerable tourism development based on the reefs, particularly for SCUBA divers. However, from 1980 to 1982, white-band disease killed over 90% of the staghorn corals (Acropora cervicornis) in shallow waters, and the disease also decreased the coral's ability to regenerate after physical damage. Like other parts of the Caribbean, the black-spined sea-urchin, Diadema antillarum, almost died off in 1983. Reefs on the southern and western coasts have been severely degraded by recreational uses, and by various kinds of pollution, including pollution from an oil refinery, which closed in 1985 but re-opened in 1992. Corals, reef fish,

and other organisms have been legally protected since 1980, effectively banning spearfishing and the collection of corals. Legislation exists to establish protected areas; but no protected areas have been created, although this is considered a priority. Elements in the private sector have become active in protection of the reefs, with initiatives such as installing mooring buoys at major diving sites, and an annual reef-care clean-up programme.

Cayman Islands

Grand Cayman, Little Cayman, and Cayman Brac, are small, low islands (33 km by 10 km, 14 km by 3 km and 17 km by 3 km, respectively) to the southwest of Cuba. The islands have well-developed fringing reefs on the narrow shelves around them, which end as steep walls dropping to great depths. The Cayman Islands have grown phenomenally in the last 30 years, from an undeveloped country, to a thriving financial centre and popular tourist destination. The resident population has grown from 8500 to 30,000, but 600,000 people visit on cruise ships, and another 280,000 tourists, including many divers, come each year. Seafood is really popular, and there are considerable pressures on stocks of conch, lobster, and fish.

Hurricanes can cause major impacts, such as caused by Gilbert in 1988. As in the rest of the Caribbean, Diadema antillarum died out in 1983, but this did not result in an algal bloom, because grazing fish were still abundant. Now the Diadema seem to be coming back in areas on west Grand Cayman. There was large-scale bleaching of corals in 1987, and even worse bleaching in 1995–1996 and 1997–1998. White-band disease has been seen, but the staghorn (Acropora) coral species are still common, although impacted by storms. The deeper reefs off George Town have been destroyed by the continual anchoring of cruise ships, and nearby shallow reefs have been damaged by the resulting sedimentation. Another major source of stress on the reefs is from the thousands of divers.

The condition of most Cayman reefs is relatively good, but veteran divers say they are deteriorating. The government is starting monitoring, in addition to the two CARICOMP sites, and has banned the taking of any marine life using SCUBA. Fishing of conch, lobster, and turtle is controlled, and the discharge of harmful effluent and raw sewage is banned. There is now concern about polluted groundwater seeping out into coastal waters, because much sewage is disposed of by deep well injection. Reef fish are still abundant, although the increasing use of large Antillean traps with small mesh wire is causing concern. The government has established Marine Park Zones (only line fishing from the shore or out in deep water); Replenishment Zones (no spearfishing, no collecting of conch or lobster, and no fishtraps); and an Environmental Zone (no hunting, fishing, swimming, or anchoring). These zones include about 34% of coastal waters, and are enforced by four full-time Marine Enforcement Officers, backed up by the possibility of heavy fines.

Colombia

The Caribbean coast of Colombia has a 40 km wide continental shelf, which is strongly influenced by freshwater and sediment runoff. In the centre is the Magdalena river, the largest river discharging directly into the Caribbean Sea. There are about two million people living on the Colombian coast, mostly in three port cities Barranquilla (large and industrial), and Cartagena and Santa Marta, which are dependent on tourism. There are significant human impacts in the coastal zone from sewage and chemical pollution, coastal construction, over-fishing, dynamite fishing, mangrove logging, and tourism. Sediments cover most of the shelf and there are few coral reefs near the mainland.

There are many well-developed reefs around offshore islands, including the Islas de San Bernardo and the Islas del Rosario on the shelf, and a few distant coral banks and atolls (the Colombian archipelago of San Andres and Providencia). San Andres is densely populated with about 50,000 people in 30 km^2. It is an active commerce and tourism centre, and human impacts on the reefs include sewage pollution, dredging, coastal construction, over-fishing, tourism, oil pollution, and boat and anchor damage. There are few hurricanes this far south, but the San Andres archipelago suffers occasional impacts. Diadema died out in 1983, there were mass mortalities of gorgonians in the 1980s, and significant coral bleaching in the 1980s and in 1995.

The reefs of Punta Betin and Isla Morro Grande are impacted by pollution and sediment, and have fewer coral species (20) and less coral cover (19–26%), than the reefs of the Tayrona National Park, where few people live (a CARICOMP monitoring site with 26 coral species and 37–49% coral cover). Human impacts have probably affected coral reproduction, as colonies of Montastrea cavernosa had smaller gonads and lower fertility on the polluted reefs. Moreover, there are now fewer coral species and lower coral abundance at Punta Betin than in 1972 and 1975, which also suggests that pollution from Santa Marta Bay is affecting the reefs. In the last 10 years, there has also been extensive mortality of branching (Acropora palmata, A. cervicornis, Porites porites) and foliose (Agaricia tenuifolia) corals in shallow waters at Tayrona, and considerable mortality of massive corals (Stephanocoenia intersepta, Montastrea annularis, Colpophyllia natans, Diploria spp.) in deeper water.

Extensive coral mortality has occurred around the coral reef islands near Cartagena: Islas de San Bernardo and Islas del Rosario. Acropora species, P. porites and Ag. tenuifolia were severely affected, and some massive corals also declined. The reefs of San Andres were healthy from 1968 to 1973, but they were found to be in poor condition in 1992, with about 52% of the coral recently dead. The corals most affected were Acropora cervicornis (which has almost disappeared from around San Andres), Ac. palmata, Eusmilia fastigiata

and C. natans. Since then, many algae have proliferated (mainly Dictyota, Halimeda, Lobophora and Padina).

Similar results were seen at the three unpopulated atolls of San Andres and Providencia (Courtown, Serrana, and Roncador) in 1994–1995. The amount of recently dead coral was between 43% and 56%, with the most affected species being branching (Acropora spp., Porites porites) and massive corals (Montastrea annularis, Siderastrea siderea, C. natans, Diploria spp.). However, the mortality of the two Acropora species and Gorgonia spp. were much lower than on San Andres.

Environmental management was boosted by creation of the Ministry of the Environment in 1993, which administers national parks and reserves, including Tayrona and Islas del Rosario. Both have some local rangers to enforce regulations, but resources and infrastructure are still insufficient for effective control. Management plans and legislation are being prepared for these and other proposed protected areas (including Islas del San Bernardo, San Andres, and Providencia). Legislation and regulations are also being prepared for coastal area management and further protection of mangroves, seagrass beds, and coral reefs. A nation-wide monitoring programme, on both Atlantic and Pacific coasts, was introduced in 1998.

Jamaica

The large island of Jamaica (235 km by 80 km) is in the centre of the Caribbean Sea. Cuba, 150 km north, moderates the effects of the northeast trade winds on the well-developed fringing reefs of the north coast, which grow on a very narrow shelf. Patchy reef formations on the south coast grow on a shallow shelf up to 20 km wide, but are punctuated by rivers and sediment slopes. Reefs and corals also grow on neighbouring banks at the Pedro Cays, 70 km south, and the Morant Cays, 50 km southwest. The Jamaican population has doubled in the last 30 years to about 2.5 million. There are many coastal communities, industries are concentrated on the southeast around Kingston, and there has been much recent tourism development on the north coast.

Jamaican reefs suffered little storm damage for more than 30 years, until they were severely impacted by Hurricane Allen in 1980. In the same year, there was some white-band disease in Acropora cervicornis, while in 1983, the abundant sea-urchin Diadema antillarum died off. These combined natural impacts marked the beginning of a major deterioration of Jamaican coral reefs. The reefs did not recover because of insidious, chronic human disturbance, notably over-fishing, and increased sediment and pollution runoff. Over-fishing on the narrow north-coast shelf was obvious in the 1960s, but the unusually high abundance of Diadema

grazed down the algae and allowed the corals to dominate. When the Diadema died, algae grew over the reefs, smothered living corals, and prevented new corals settling. This algal growth was helped by nutrient pollution and the removal of grazing fish.

Soil erosion has been a major problem in Jamaica for 50 years, and sedimentation is damaging the reefs near river mouths. Nutrient pollution has increased as human populations grew, particularly in Kingston Harbour and near coastal communities, where nitrates percolate through porous limestone onto the reefs. Increased coral mortality occurs to the west of Kingston Harbour, showing the impact of a pollution plume. Jamaican corals also suffered mass bleaching in the winters of 1987, 1989 and 1990, with considerable mortality.

In the late 1970s, nine reefs on the north coast had coral cover averaging 52% at 10 m depth, but this declined to 3% in the 1990s, in parallel with an increase in fleshy macroalgae from 4% to 92%. Even in areas once dominated by massive corals at Discovery Bay, coral cover is only about 10%, and 14% in Montego Bay Marine Park. In shallow water, where sea-urchin numbers have increased, opportunistic corals have recruited and cover is increasing slightly. Some coral populations around the Port Royal Cays are in good health (coral cover up to 20%) with abundant Acropora cervicornis.

For many years, the main law controlling coastal development was the Beach Control Act (1960), which licensed construction or drainage works near the shore. However, it was easy to ignore. Environmental management has been greatly strengthened by the Natural Resources Conservation Act (1994), and increased staffing of the Natural Resources Conservation Authority, in the Ministry of Environment and Housing. The Ocho Rios and Montego Bay Marine Parks were classic 'paper parks' with no staff or funding until 1989, when the Montego Bay Park was revitalised with USAID funding. In 1998, new land/sea coastal management areas have been created at Negril and the Portland Bight. Also in 1998, the potential for better integrated management of the coastal zone received a boost with the formation of a Council on Ocean and Coastal Zone Management, on which all major sectors are represented, and which reports directly to Cabinet.

Government efforts in conservation and reef management have been increasingly supplemented by NGO activities. Local groups have formed all around the country, and several are doing valuable work in the coastal zone (Negril Coral Reef Preservation Society, Portland Environmental Protection Association, St. Ann Environmental Protection Association, and Caribbean Coastal Area Management Foundation). The Fisheries Improvement Programme, at the Discovery Bay Marine Laboratory, is helping artisanal fishermen to manage their own fishery resources. The CARICOMP monitoring site at

Discovery Bay is soon to be joined by others at Portland Bight and Montego Bay. In addition, long-term monitoring for the effects of climate change is to be carried out for the Caribbean Planning for Adaptation to Climate Change project.

Netherlands Antilles

Bonaire (38 km by 10 km) and Curacao (61 km by 14 km) are small oceanic islands about 70 km north of Venezuela. Each lies on a northwest to southeast axis, with the east coasts exposed to persistent trade winds. The shelf around each island is narrow, about 8–12 m deep for about 100 m, then the shelves slope steeply to a sandy terrace at 50–60 m, and then drop off. Coral reefs are well developed on the leeward coasts, but on the windward coasts, the shallow areas are dominated by crustose algae and Sargassum, and the corals grow best in deeper water.

Tourism is the most important industry in Bonaire, increasing at 10% per year for the last 10 years. The resident population is about 11,000 and growing, while there are about 60,000 visitors per year, of whom 26,000 are divers. Building along the coast is booming for tourism and housing, but sediment runoff is increasing from this construction, and there is no central sewage treatment. Fishing is mostly for pelagic fish, and is rare on the reefs.

Curacao has a population of 160,000, which is decreasing, while environmental pressures are increasing dramatically. The economy is based on oil refining, other industries, tourism, and off-shore banking. Massive coastal development is the biggest threat to the reefs, with raw sewage discharge, harbour pollution, and sedimentation from deforestation. Most fish caught are pelagics, with the reef fish catch estimated at 90–180 tonnes per year.

Bonaire and Curacao are on the margin of the hurricane and storm belt. But when hurricanes and storms do impact, their effects are marked. White-band disease caused similar massive damage to Acropora cervicornis in 1980–1981 as it did at Aruba. Diadema antillarum died off in 1983, with a parallel increase in large algae. There was mass bleaching of corals in 1987, 1990, and 1995.

Coral cover at four sites on Curacao and Bonaire decreased from 55–50% to 30–25% at 10 m and 20 m between 1973 and 1992, but was mostly unchanged at 30 m and 40 m depth. The decreases are probably due to increased growth of large algae and ascidians because of increased pollution.

The general condition of Bonaire reefs is good, and the impact of anchoring and sewage pollution is localised. Reef fish are abundant and biomass is high. The healthiest reefs in

Curacao are upstream of the population centres, away from pollution by coastal development and industry. The reefs are also protected by rougher waters and poor access for the public, and pressure from fishing and diving is limited. Elsewhere, the condition of reefs and fish populations have degraded.

The Bonaire Island government introduced marine resource management in the 1970s, banning spearfishing and collection of coral. The Bonaire Marine Park (created in 1979) now extends all around the coast, and like other parks in the Netherlands Antilles, it is administered by a private foundation (STINAPA Netherlands Antilles). There are zonation and management plans, CARICOMP monitoring, permanent moorings, and a visitor centre. The Park is completely self-financed by diver fees of US$10 per year, grants, and donations. The Reef Management Ordinance (1976) prohibits spearfishing and collection of coral in Curacao, and is still the only legislation. The Curacao Underwater Park (20 km from the eastern tip, Oostpunt, to the capital Willemstad) was opened in 1983, but has no legal status, and is ineffective due to a lack of funds. A management plan was produced in 1995, and legislation is being upgraded to start management in 1997. Meanwhile, a CARICOMP site has been operated since 1994.

Venezuela

Reef coral development is limited by freshwater and sediment runoff, and cool upwellings. Nearshore coral reefs are scarce, with small reefs at Moroccoy and Mochima. Better reefs occur around offshore oceanic islands, which include the Archipilago Los Roques. There has been much industrial, urban, and tourist development on the coast, with consequent sediment, human, and industrial pollution. There is intensive fishing on the fringing continental reefs and at Los Roques (lobster, conch, and fish). The island reefs are less exploited for tourism, but there is no control.

Hurricanes are relatively rare. There was mass mortality of Diadema in 1983, and large-scale bleaching of corals in 1987, and much more in 1995–1996. Some reefs are currently affected by terrestrial runoff. Recently, there has been mass mortality of marine organisms on the Moroccoy National Park reefs, which eliminated almost all massive coral species. Previously, the cover by massive species alone had been relatively high, at 36%.

Conservation is the responsibility of MARNR; INPARQUES manages protected areas and the national parks at Los Roques, Mochima and Moroccoy. There are many laws, regulations and management plans, such as declaring the coastal strip 80 m wide, including the mangroves, as a protected area, but there are insufficient boats, trained personnel, and funds, and the laws are not fully implemented. The navy controls many oceanic islands, restricting tourism

and fishing. Some NGOs support reef research programs, for example ECONATURA gives grants for small projects in protected areas, and trains personnel to monitor physical and chemical variables in marine parks. FUDENA maintains a marine turtle conservation programme. CARICOMP sites are located at Moroccoy and Margarita Islands.

Recent management activities

Two significant resource management trends can be seen in the region. First, there is a progression from protecting species, to protecting habitats, then to protecting the wider ecosystem and, ultimately, nation-wide environmental management. No countries have reached that goal, however, most have established marine protected areas (MPAs), mostly as national parks. Most receive too little funding to be fully effective, but they play a valuable role in attracting public and government attention to the importance of natural resources. They stimulate Integrated Coastal Management (ICM) and become valuable centres for learning, and developing appropriate measures, although mostly on a small scale. Integrated management is still hampered by the multiple agencies involved, but some countries (e.g. Cayman) have created more unified structures for environmental decision-making by restructuring departments and creating consultative committees (as in Jamaica).

The small island states of Bonaire and Cayman depend heavily on marine resources and have established more effective conservation mechanisms than the nearby islands of Curacao and Jamaica, where there are many more competing interests. Cayman recently declared a moratorium on development, while Bonaire and other 'island paradises' have not yet established carrying limits.

The second trend is a move from 'top-down' control by government, to 'bottom-up' participation by local resource users and development of co-management. Enforcement of environmental laws requires political will, trained staff and money. Most natural resource agencies are understaffed, and rangers either do not enforce environmental laws, or impose minimal fines. Environmental management by governments is expensive and inefficient; whereas management by an informed and involved population is cheaper and more likely to succeed. As people become aware of environmental issues, politicians follow. In the last 10 years, environmental managers and funding agencies have increased the involvement of all 'stakeholders' in environmental planning and regulation. There has been much talk, and some action, towards co-management in the region, and the participation of NGOs in coastal management has increased. They are contributing to reef monitoring in some cases in association with CARICOMP, which is represented in five of the six countries. In addition, assessments were made for Reef Check in 1997, in Cayman and Bonaire.

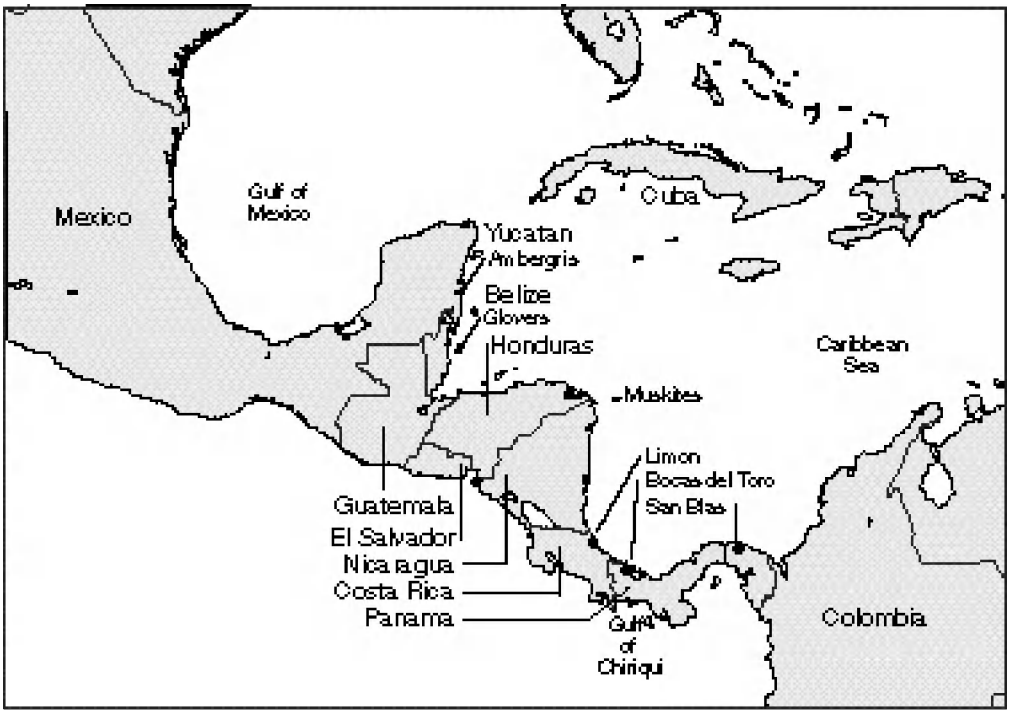
The authors for this review were: Jeremy Woodley, University of the West Indies, Jamaica; Kalli De Meyer, Bonaire Marine Park; Phillippe Bush and Gina Ebanks-Petrie, Department of the Environment, Grand Cayman; Jaime Garzon-Ferreira, INVEMAR, Colombia; Eduardo Klein, Universidad de Simon Bolivar, Venezuela; Leendert Pors, Ecological Institute, Curacao; and Cornelius Wilson, Ministry of Transport, Communication and Utilities, Aruba.

11. Status of coral reefs of Central America: Pacific and Caribbean coasts

Jorge Cortés and Marea E Hatziolos

Abstract

Reefs on the Pacific and Caribbean coasts of Central America are remarkably different. The Pacific coast reefs are small with very low diversity and are under very high pressure from natural impacts and increasing human activities. The reefs have been heavily damaged in the past by crown-of-thorns starfish predation and massive bleaching during El Niño years, and now by large amounts of sediment runoff from poor land-use practices. They are also being continually stressed by cold upwellings and damage from bioeroding animals that burrow into coral skeletons and scrape off newly settled corals. These poor coral growth conditions also result in a low capacity to recover from damage. There has been little activity to conserve them, and pressure is not high for protection, except for a few reefs well offshore.



The eastern coast of Central America has some of the best reefs in the Caribbean. Reefs off Belize, and also those well offshore of countries to the south, have much higher biodiversity and are generally in good to excellent condition; corals are healthy and some reefs have large fish populations. These reefs have been impacted by coral bleaching, including the current episode, and by the death of the long-spined sea-urchin. But they have generally recovered rapidly. They are now being impacted by increased sediment and nutrient runoff from poor land-use practices, and by increasing fishing pressure, often using illegal means. This is particularly clear in reefs off Panama where significant degradation has been measured. There are a number of marine protected areas (MPAs), some well managed but others existing only on paper. Currently there is a major regional project in preparation, under the Mesoamerican Barrier Reef Initiative (MBRI), which aims to increase the capacity for conservation and sustainable use of coral reefs along the northeastern coast of Mesoamerica, and to increase monitoring and assessment of the health of coral reef ecosystems.

INTRODUCTION

The reefs of the two coasts of Central America are radically different: those on the Pacific side are generally small, have very low coral species diversity, having formed along the margins of a steep and narrow continental shelf, and are subject to the influences of upwelling and El Niño. In contrast, reefs on the eastern side have some of the highest coral diversity in the Caribbean, and have formed extensive coral reefs along shallow underwater banks. These include the barrier reef running parallel to the coast of Belize, one of the longest in the world. The Mesoamerican Barrier Reef System covers a distance of nearly 1000 km, originating in the northern Yucatan Peninsula in Quintana Roo (Mexico), and extending as far south as the Bay Islands off the north coast of Honduras. Further south, fringing reefs and the many offshore coral cays from Nicaragua to the San Blas Islands of Panama form a second cluster of reefs with associated mangroves and seagrass beds. Research to date has focused on the ecology and geology of the reefs of Panama and Belize. Only recently have reports of degradation in Mesoamerican reefs begun to focus attention on the need for conservation and management of these systems, and hence a better understanding of their structure and function within a larger regional context.

The Caribbean reefs of Mesoamerica are ecologically complex and subject to a variety of natural and increasing anthropogenic stresses. Coral bleaching was a major event in 1983, causing massive mortality of corals. Hurricanes are a major natural disturbance, periodically destroying vast areas of reefs and clearing the way for new settlement and colonization, particularly in northern parts (as occurred recently with Hurricane Mitch). The long-spined

sea-urchin Diadema antillarum played a major role on these reefs, as in the rest of the Caribbean, in controlling the growth of macroalgae. When there was a mass die-off in 1983, algal growth exploded and smothered large areas of coral reefs in most countries, except in Belize where near-normal populations of grazing fish remained. In most other areas, fish populations were reduced through the use of fine mesh fish traps, nets and spearfishing. The most recent bleaching event associated with the 1997–1998 El Niño has had marked effects in the western Caribbean, as elsewhere. The overall mortality from this event is still being assessed, but individual accounts indicate that it is extensive. Recovery rates are likely to be affected by cumulative stress from other anthropogenic sources. These include destructive fishing practices, including inappropriate gear, the use of spear guns, and violation of closed seasons and exploitation of spawning aggregations of reef fish, and indirect sources such as pollution and sedimentation.

Deforestation and inappropriate land use in watersheds draining to the Caribbean have resulted in significant erosion and sediment loads affecting reefs. Non-point source pollution from pesticides and agricultural runoff, as well as wastewater from growing municipal and industrial development along the coast, are degrading coastal water quality and contributing to eutrophication. Coastal tourism and port expansion have resulted in habitat loss and degradation through conversion of mangroves, dredging of seagrass beds, and siltation of reefs. These interactive and cumulative effects are likely to play an increasing role in the dynamics of reef community structure and their resilience to natural disturbance.
Reefs on the Pacific coast are subject to frequent bouts of cold upwelling water, which favour the growth of macroalgae and limit the growth of corals. By contrast, during El Niño years, seawater temperatures can rise to over 30°C and stay high for weeks, resulting in coral bleaching. Coral diversity is very low because these reefs are isolated from the Pacific centres of high diversity by enormous distances, and from the Caribbean side by land that closed the connection between the two seas 3.5 million years ago. The reefs are usually close to land and are heavily impacted by large amounts of sediment runoff because of heavy rainfall. There is also intense bioerosion by burrowing sea-urchins, boring molluscs, and other animals. This erosion is so intense that most of the reefs are decreasing in coral rock content, not increasing like most other reefs in the world. The crown-of-thorns starfish are persistent predators on these reefs and have caused serious damage in the past.

The combination of stresses on Pacific reefs means that there are very slow rates of recovery following major stress. After the large El Niño bleaching in 1983, it has been estimated that recovery of these reefs may take between 100 and 200 years. Coral reefs that are stressed by either cold upwellings or pollution could take longer to recover.

Belize

The longest barrier reef in the Caribbean runs from Belize's northern border with Mexico, north of Ambergris Caye, down to Honduras, a distance of some 250 km. Virtually all types of reefs are found, from shallow platform reefs in the lagoon to deep plunging barrier reefs on the edge of the shelf. A series of oceanic atolls are found outside the reef; among these are Turneffe, and two of the best examples of oceanic atolls in the Caribbean, Lighthouse and Glover's Reef. These reefs are probably the best reefs in the Caribbean, as they are in excellent health, have a high diversity of corals, and large fish populations. The major natural impacts are hurricanes, which strike every six years on average, the most severe being Hattie (1961) and Greta (1978), which damaged corals and sent 2 m storm surges over some islands. The recent coral bleaching in late 1998 appears to be particularly severe, with large areas of the reefs showing extensive bleaching of almost all species, and water temperatures rising to 32°C and as high as 38°C in protected shallow areas.

Most reefs are relatively remote from the mainland. A lagoon, between 10 km and 40 km wide, separates the barrier reefs from the mainland and protects them from sediment runoff and pollution. In addition, Belize has one of the lowest population densities in the Caribbean and most of the tropical and mangrove forests are intact. Fishing pressure is slight to moderate, however there is increasing pressure from fishers coming up from countries to the south. When the Diadema died off in 1983, there were no major increases in macroalgal growth due to a healthy population of herbivore fish, and so there were few impacts on the corals. The offshore atolls are remote from land influences, however they appear to have reasonably high natural levels of water nutrients and are experiencing increasing fishing pressure.

The excellent status of reefs in Belize is attracting increasing numbers of dive tourists, many of whom explore the reefs aboard small ships. The government is active in promoting coastal conservation and is implementing a phased integrated coastal management program. Belize also signed the Tulum Declaration along with its neighbors: Mexico, Honduras, and Guatemala. These four countries are committed to joint management and conservation of the Mesoamerican Barrier Reef System (MBRS), having acknowledged the need for a coordinated plan of action. A regional project to protect the reefs through better monitoring and conservation techniques is now being prepared with Global Environment Facility and World Bank support, and standards and protocols for sustainable use are being introduced. The Mesoamerican Barrier Reef Initiative (MBRI) is part of a larger program to preserve and expand a biological corridor of natural habitats, connecting populations of flora and fauna along the entire Mesoamerican isthmus, from Mexico to Panama.

Costa Rica

Most of the Caribbean coastline consists of sandy beaches with occasional rocky headlands where reef corals grow. There are reefs on offshore carbonate banks in the north, and small areas of fringing and patch reefs down to the Panamanian border. These reefs are exposed to strong onshore winds and waves that limit growth in shallow water. There are also large sediment flows that restrict reef growth, and these sediment flows have increased in the last 20 years. The reefs were extensively damaged by major bleaching in 1983, and algal proliferation from the Diadema die-off, also in 1983. Reefs around the port of Limon have been damaged by sewage, industrial and petroleum pollution. Recent increases in sediment flow have caused considerable damage to coral cover on the large fringing reefs of the Parque Nacional Cahuita (from an average of 40% in the early 1980s to around 11% now). Likewise there has been a major drop in coral cover (now less than 20%) in Refugio Nacional de Vida Silvestre Gandoca-Manzanillo, but here corals are mostly healthy. Other problems for the reefs are coral and sand mining, and dumping of solid wastes. Intensive citrus and banana farming have resulted in pollution from pesticides, fertilizers, and sediment. Both MPAs have had a massive increase in tourist numbers (a three-fold increase between 1981 and 1991).

On the Pacific coast, the fringing reef of Punta Isolotes, Golfo Dulce (near the border of Panama) has been massively degraded by sedimentation, such that coral cover is down to 2%. This was a well-developed reef with a high cover of Porites and Pocillopora corals, but now the reef is virtually extinguished. The best reefs are those of Culebra Bay in the north. These are also under increasing pressure from land runoff and fishing activities, including collection of ornamental fishes and corals. Attempts at protecting these reefs are meeting with resistance from other stakeholders.

Management of Costa Rican reefs has mostly focused on protected area management rather than control of land-based sources of pollution, sedimentation, and other offsite impacts that have devastating effects downstream.

El Salvador

There are a few small reefs at Los Cobanos, which are heavily impacted by land stresses: sediment pollution, and bioerosion. Little is known of these reefs.

Guatemala

The Caribbean coastline is very short and heavily influenced by sediment-laden rivers, thus, there is virtually no coral reef growth near the coast. The Pacific coast is also influenced by alluvial conditions and dominated by mangroves, with negligible coral reef formation.

Honduras

There are three main reef groups: nearshore fringing reefs; extensive offshore fringing reefs around the Bay Islands (Utila, Roatan, and Guanaja), Cayos Cochinos and Islas del Cigne in the north central region; and the offshore fringing and patch reefs of the Caya de la Mosquitia (Mosquito Cayes). The Bay Islands have a well-developed structure and high coral diversity, with 44 species known from these islands. A complete inventory of marine biodiversity of the Bay Islands will be undertaken as part of a five-year Natural Resources Management Project for the Bay Islands, supported by the Inter-American Development Bank and the Government of Honduras. A biodiversity monitoring and geographic information system will also be established under the project. This type of monitoring will be critical in assessing the status of coral reefs in this region following the significant bleaching and coral mortality experienced in these otherwise healthy reefs after the El Niño event of summer 1998. This was followed soon after by the devastating Category IV Hurricane Mitch, which struck the coast of Honduras with 155 mph winds in late October. Such natural disturbances, coupled with the prospects for rapidly increasing tourism and migration from the mainland to the Bay Islands, underscores the vulnerability of these reefs and the need for pro-active management. A new marine reserve for the waters around the Bay Islands is under preparation, which will limit fishing and regulate other marine activities. Other plans include control of land-based sources of stress through better land-use planning and environmental management. Elsewhere, for example along the Mosquito Cayes, fishing pressure is more intense and few fish on inshore reefs reach reproductive size. As a consequence, there is significant growth of algae that smothers corals and impedes their growth in areas with high nutrient loads.

As a participant in the Mesoamerican Barrier Reef System Initiative, Honduras will be part of a regional program involving neighboring Belize, Guatemala, and Mexico in monitoring and assessment of coral reef health. Biophysical and socioeconomic information will be processed and disseminated around the region to help build a picture of ecosystem health at the local, national, and regional levels.

There are no reefs on the short Pacific coast of Honduras, which is part of the Gulf of Fonseca, a highly productive zone of upwelling and continental runoff.

Nicaragua

There is little information on reefs off both coasts of Nicaragua, but on the east coast there is the largest hard carbonate bank in the Caribbean. On it there are patch and island coral reefs but these are largely unknown. There are four groups: Moskitos Cays; Man-of-War Cays; Cayos de Perlas; and Great and Little Corn Islands. Human occupation of these last islands is resulting in degradation from sewage pollution and over-fishing. There are no reefs off the

mainland coast because of the large amounts of sediment runoff. No reefs are reported from the Pacific coast.

Panama

Panama is protected from hurricanes and cyclones because it is south of the path of most tropical storms. There is, however, frequent upwelling on the Pacific coast, which limits coral reef growth. Both coasts have experienced coral bleaching in association with El Niño events, the most severe in 1983. The most recent El Niño episode (1998) resulted in only moderate coral bleaching on both the Pacific and Caribbean coasts.

There are three large areas of reefs on the Caribbean side: Bocas del Toro; Region Central from Colon to Portobelo; and the several hundred islands of San Blas. A wide range of reefs occur at Bocas del Toro, ranging from those near the shore and mangroves that are subject to heavy sediment influence, to offshore patch reefs growing down to 15 m in pristine clean water. Exposure to large waves limits coral growth in shallow water to hardy, stunted corals. Behind these are extensive areas of seagrasses, and mangroves with patch reefs, which have low coral cover (less than 20%) because of large sediment flows and high algal overgrowth. Fishing pressure is particularly high, and large fish, lobster, and conch are rare.

The reefs of the Central Region were studied intensively following a major oil spill in 1987. There are mostly shallow fringing reefs in this area in less than 6 m of water, with some extending to depths of 12 m. The oil spill at Bahia Las Minas decreased coral cover and diversity, mainly because the oil was trapped in the mangroves, and continually leached out onto the shallow reefs over many months.

In the 1970s, the San Blas reefs were healthy, with active growth extending down to 30 m and coral cover around 30–55%. There were extensive stands of Porites porites and elkhorn coral (Acropora palmata) in shallow water, with deeper zones dominated by Agaricia agaricites. Recent studies have shown that more than half of these corals have been lost (now 12–26% cover), either covered in sediment, broken into rubble or, like the Porites, mined for calcium carbonate. These losses are attributed to a combination of many causes including: the die-off of Diadema, which has encouraged algal overgrowth; coral bleaching; increased sediment and nutrient loads from limited agriculture; unplanned coastal development; and coral mining. Algal cover has doubled since the mid-1980s to about 60% on many reefs. The greatest damage has occurred around the 41 inhabited islands near shore with direct disposal of all effluents onto the reefs, and expansion of the islands by infilling the seagrass beds. Fishing pressure, particularly by spearfishing and seine nets, is intense, and local regulations for sustainable management of the resources are

ignored. Grouper, lobster, and turtles are exported and their populations are now very low. Coral bleaching in 1983 killed many corals down to 20 m, particularly the dominant coral Agaricia agaricites, whereas the bleaching in 1995 had little impact.

Pacific reefs are mostly small and have low coral diversity with a maximum of 23 coral species, and growth is limited by cold upwellings that promote massive algal blooms and assist large algal growth. Coral growth in the Gulf of Panama occurs almost exclusively as fringing reefs off the islands of Iguana and Pearl. To the north, in the Gulf of Chiriqui, there are reefs both on the mainland and around offshore islands away from oceanic waves. The Coiba Island reef is probably the second largest in the eastern Pacific and covers 160 ha. These reefs were extensively damaged during the 1983 El Niño bleaching event, and have still not recovered.

One coral reef area on the Pacific coast, Coiba, is within a MPA. There has been active cooperation between the local inhabitants of the San Blas Islands, the Kuna Indians, the Smithsonian Tropical Research Institute, and the Panamanian Government to establish the Kuna Biosphere Reserve.

Overall status of reef management

Perceptions of the need for greater reef management have increased with the recognition of the economic value of reefs for tourism and fisheries. This recognition has meant strong development of marine protected areas (MPAs) in Belize and Costa Rica, while Honduras, and to a lesser extent Panama, lag behind. Conservation has been aided by the peace processes between neighbouring countries, and Belize, Guatemala, Honduras, and Mexico are collaborating in a joint initiative for the conservation and sustainable use of the Mesoamerican Barrier Reef System with the assistance of the GEF, the World Bank, and a variety of donors working at the national and regional levels.

These countries have been participating in reef productivity monitoring through CARICOMP (Caribbean Coastal Marine Productivity Program), and research on reefs has been strong in Belize (largely with collaboration from British institutions), and Panama (through collaboration with the Smithsonian Institution of the USA). A more comprehensive ecosystem monitoring and environmental information systems effort will be mounted at the sub-regional level for countries participating in the MBRI.

There are more than 20 MPAs designated along the Caribbean coasts of these six countries, however only a small fraction have effective management plans and staff to assist in conservation. A greater proportion of the reefs of the Western Caribbean will be under

protection and active management as part of ongoing national and sub-regional efforts in Mexico, Belize, and Honduras to expand the system of marine protected areas to cover the rich biodiversity and biogeography of the region. Similar efforts will need to be mounted in Nicaragua, Costa Rica, and Panama to ensure that such coverage is truly representative of the region as a whole.

Coral reefs on the Pacific side are poorly developed and generally in poor condition, thus there is little appreciation of these reefs for management. These reefs are heavily stressed by natural and human stresses and recover very slowly from damage. Only two MPAs have been notified: one by Costa Rica on the offshore islands Isla del Coco and another, Coiba Island, off the Gulf of Panama coast.

Conclusions

The region contains a mixture of very good coral reefs, such as those off Belize, but the majority are coming under increasing stress from human activities, combined with the normal natural stresses, resulting in reduced resilience and many degraded reefs. This is particularly the case on the Pacific coast, but these reefs were always marginal and have very low capacity to recover. Current management capacity is generally poor, but there are encouraging signs of greater commitment to conserve the valuable Caribbean reefs in particular.

Jorge Cortés is from the Centro de Investigacion y Ciencias del Mar y Limnologia and the Universidad de Costa Rica in San Pedro, and Marea Hatziolos is senior coastal and marine resources management specialist at the World Bank in Washington, D.C., with projects in Central America.

12. Reef Check and sustainable management of coral reefs

Gregor Hodgson

Abstract

Reef Check is a global program that began in 1997 to monitor coral reef resources, to raise public awareness about the problems facing coral reefs, and to look at solutions to the problems. In its first year, the Reef Check teams surveyed over 300 reefs in 31 countries and territories. Results indicated that few reefs were unaffected by human activities, even very remote sites. Over-fishing has reduced high-value indicator organisms such as lobster, sharks and grouper to low levels at most reefs, including some within marine protected areas.

In 1998, over 40 countries are participating in the second annual Reef Check survey, which demonstrates that this volunteer survey has succeeded in raising public awareness about reefs around the world. Preliminary results released at a press conference in Hong Kong on 19 November show that extensive bleaching and mortality of corals has occurred in parallel with the massive 1997/98 El Niño event. Mortality on a scale never previously reported is occurring, including some corals that have previously survived for centuries.

The catalyst for reef monitoring

A meeting of senior coral reef scientists and managers from all over the world was held in Miami in 1993 to determine whether recent reports of global reef decline could be verified. There were many individual stories of reef degradation, but there were insufficient data over broad areas of coral reefs to determine any clear patterns. Many reefs in the Caribbean, south-east Asia and Africa were severely damaged, but large tracts of reefs in the Pacific and Indian Oceans were apparently unaffected and in near pristine condition. This situation catalysed two global coral reef monitoring programs — Reef Check and the Global Coral Reef Monitoring Network (see following essay).

The Reef Check program aimed to tap into the large pool of enthusiastic volunteer SCUBA divers who often travel to places inaccessible to reef scientists. Scientists at the Hong Kong University of Science and Technology developed a set of methods to assess coral reefs

rapidly, based on the well-recognised methods used by the Global Coral Reef Monitoring Network. The assessment methodology was designed to be learnt in a day by non-scientist divers and then applied in teams led by one competent marine biologist. The methods set out to measure the percentage cover of living coral, and then to record the presence of key indicator species that could be easily recognised — lobsters, giant clams, and the major fish species targeted by local fishermen, such as grouper, snapper, parrotfish, and humphead wrasse, or easily recognised reef fish, such as butterfly fish. The methods can be viewed on the Reef Check home page at http://www.ust.hk/~webrc/ReefCheck/reef.html.

Mechanisms for gathering data

The Reef Check program is essentially a community project and depends upon volunteer help to succeed. Coordinators are located in many countries around the world, and they are responsible for organizing training for teams and implementation of actual surveys. Each team has a scientific team leader who is responsible for ensuring that the team is properly trained and carries out the data collection correctly. In general, while scientists are needed for training and surveys, NGOs are the best organizers for Reef Check.

In 1997, most funding was gathered by local Reef Check coordinators who organised travel and accommodation, often receiving generous contributions from tourist operators and travel companies. This year, these funding mechanisms will be supplemented by a grant from the Rockefeller Brothers Fund, which has allowed Reef Check programs to grow in Asia, especially in Vietnam, Malaysia, Indonesia, Thailand, and the Philippines. A grant from the United Nations Environment Programme (UNEP) has given a big boost to data gathering in the Caribbean. With these clear demonstrations of success, it is expected that additional funding will allow more countries and surveys to be added next year in other parts of the world.

In 1998, Reef Check and the Global Coral Reef Monitoring Network (GCRMN) formed a partnership within the International Coral Reef Initiative (ICRI). The GCRMN is focussed as a government level program, and Reef Check will expand to serve as the community-based monitoring protocol for GCRMN. This will allow sharing of coordinators, training, and survey data. In another collaboration, the 1997 data has been sent to the global database, ReefBase at ICLARM in Manila, and will be incorporated as a special unit so that everyone can have access to this invaluable resource.

The first results — 1997 and 1998

Reef Check has accomplished a number of goals. It has gathered a comparable two-year set of data as a snapshot of reef health at hundreds of locations around the world. In 1997,

the biggest surprises were that there serious over-fishing of high-value reef animals was widespread and that there were virtually no reefs that were not heavily fished, irrespective of how far they were from human population centres. In addition, marine protected areas were generally no different from nearby unprotected areas, such that management regimes do not seem to be working to conserve them. Many other results are described in the summary report on the home page above.

Reef Check has had another significant result beyond gathering data on reef status. The program has involved hundreds of individual SCUBA divers, including housewives and government ministers, in an educational process that taught them about the value of coral reefs, and the threats facing these reefs. These people often became excited about their experiences and now act as 'missionaries' in their own communities, spreading the word about the need for coral reef conservation. Stories based on Reef Check community involvement appeared in many of the major publications in the world and were featured on radio and television in dozens of languages. Slowly but surely, we are raising public awareness about coral reef conservation among the general public. Together with GCRMN operating at the government level, and the dozens of other smaller reef conservation programs operating around the world, we have stimulated a demand for coral reef monitoring in most countries with coral reefs. NGOs and research institutes in countries such as Iran and Bangladesh, with little previous history of concern for reefs, are now asking for help.

This year there have been alarming reports of extensive coral bleaching in all coral reef regions of the world. Reef Check teams are now reporting on this, and presenting an alarming picture of extensive coral death in areas where bleaching has been particularly rare before. Some reports concern losses of coral reef cover of around 80% with almost total devastation of the fast growing branching staghorn species (Acropora).

A major objective is to build awareness so that the public will request governments to do more for coral reefs and to support programs aimed at conservation and management. The end goal is to have annual (or more frequent) coral reef status reports that will attract the attention of the public, similar to other regular reports such as weather or economic forecasts.

Monitoring and raising awareness are two of the easier steps up the long ladder towards sustainable management of coral reefs. The results of monitoring enable an evaluation of reef status, so that management decisions can be made. To reach the ultimate goal will require far more resources: resources devoted to creating larger and more marine protected areas with better enforcement of regulations; more funds for aquaculture and stock enhancement

research on high-value organisms; better control of fishing; continued public education; and all this within a government framework of Integrated Coastal Management.

In 1999, we will have an unprecedented opportunity to generate more public and government support for coral reef research and conservation following the disastrous global bleaching and mortality event in 1998. The Reef Check program offers a very good opportunity for communities to get involved in solving the problems facing coral reefs.

Gregor Hodgson coordinates Reef Check out of the Hong Kong University of Science and Technology. e-mail: rcgregor@ust.hk

13. Global Coral Reef Monitoring Network: Role in conservation of the world's reefs

Clive Wilkinson and Bernard Salvat

Monitoring as a coral reef conservation strategy

The most effective way to manage coral reef resources and reduce the damaging impacts of human activities is through the direct involvement of user communities. This can only occur if people are aware of the status of reefs, their economic and cultural values, and the damage being done to reefs and probable causes. Communities must also be aware that there are solutions, and many of the solutions are within their control. The Global Coral Reef Monitoring Network (GCRMN) seeks to raise that awareness by involving all users in gathering data on the status and trends in coral reefs using basic methods. Thus, there are two critical products from monitoring: the data and information on reef status and trends; and the awareness that is generated by gathering those data. We have heard people say many times: 'we did not know how bad is was until we put the tape measure down and started counting'.

All levels of monitoring are appropriate

Monitoring and assessment of coral reefs were previously regarded as a role for coral reef scientists who had rigorous training in coral reef biology. It was assumed that precise data were necessary for reef conservation and management, but this conflicts with other success stories. For example, thousands of people around the world gather data on bird populations, distribution, and migration patterns, and many people gather weather data after careful instruction on reading a few weather instruments and observing the sky. The data are usually analysed by trained ornithologists and meteorologists, but the patterns would be nothing without observations from thousands of volunteers. We have found through the Reef Check surveys that there are hundreds of people willing to carefully monitor coral reefs. Over 80 governments, many from developing countries, have asked for assistance to monitor their coral reefs during regional meetings organised through the International Coral Reef Initiative (ICRI). The demand is there for the GCRMN.

The GCRMN recognises three overlapping levels of monitoring: community, government and research, with the intensity of monitoring increasing with each level.

- **Community** — monitoring by communities, fishers, schools, colleges, tourist operators, and tourists over broad areas with less detail, to provide information on the reef status and causes of damage. Community-level monitoring uses Reef Check methodology and approaches, which were specifically designed for people with little previous experience and qualifications, but who can be trained quickly and efficiently. The monitoring focuses on the proportion of live and dead coral, and counts of easily recognised animals of particular interest to the community — key target species such as high-prized fish, lobsters, sea cucumbers etc.
- **Government** — this is monitoring, by predominantly tertiary-trained personnel in government environments or fisheries departments and universities, for moderate coverage of reefs at higher resolution and detail. Governments will be asked to establish a series of sites throughout the country to visit every year or two to determine trends and also to assess current or planned marine protection, with comparisons of adjacent un-managed sites to assess the effectiveness of management.
- **Research** — this is high-resolution assessment over small scales by scientists and institutes currently monitoring reefs for research. This level of assessment is essential to provide the quality control for the community and government levels, and to determine accurately the causes of damage to reefs. The GCRMN will encourage and, if requested, coordinate scientific monitoring, but cannot be involved in method or site selection. These are choices for the individual scientists.

The particular value of **community**-level monitoring is the enormous number of people throughout the world who are potential participants. Moreover, many of these people have detailed knowledge of the reefs and their resources, and a direct interest in maintaining them as sustainable providers of food and services into the future. The number of people who participate in monitoring may only be limited by the enthusiasm and available time of the people able to train and supervise the collection of data. A special target will be to introduce Reef Check monitoring into schools and colleges, to involve the next generation of decision makers.

Stakeholders for the Global Coral Reef Monitoring Network

The major stakeholders are the people who live on reefs and derive some of their income from reef resources. Our stakeholders are also the millions of tourists who want to enjoy

reefs as magnificent concentrations of life — biodiversity. In addition, the governments of about 100 countries with reefs are, or will be, stakeholders in the GCRMN, thus the goal is to be particularly inclusive. International agencies, regional and global banks, nongovernmental organisations and education and marine science institutes are both stakeholders and partners.

Resource managers are special stakeholders in the GCRMN because they require information and data for planning. However, there is need to recognise that resource managers often have to make urgent decisions, which need to be made before an appropriate scientific monitoring program can be designed and implemented. There often remains a gulf between what research scientists offer and what management really want, thus the GCRMN aims to work with reef managers to bridge that gap. One particular theme of the GCRMN is to monitor marine protected areas to guide managers in selecting the correct management strategies.

GCRMN principles and strategies

The GCRMN emphasises the involvement of local communities in monitoring with equal emphasis on biophysical as well as socioeconomic data. Wherever possible, the GCRMN involves existing organisations and networks, integrates existing monitoring programmes, and maintains flexibility to incorporate different methods of monitoring, other than the 'standard methodology'. The Network must be responsive to reef users and provide feedback in an understandable format. The main activity will probably be introducing or strengthening the capacity to examine reefs by providing a consistent monitoring program that will identify trends in coral reefs and discriminate between natural, anthropogenic, and climatic changes.

A full range of all reef types will be monitored, with particular emphasis on existing or planned marine protected areas (MPAs) to provide data on the resources and effectiveness of management. This will be coordinated with the World Bank, IUCN/CNPPA, GBRMPA Global Representative System of Marine Protected Areas project for site selection and questions asked by MPA management.

History of the GCRMN

In the early 1990s, international agencies recognised that reefs were declining and formed the UNEP-IOC-IUCN-WMO (United Nations Environment Programme, Intergovernmental Oceanographic Commission of UNESCO, World Conservation Union, World Meteorological Organisation) Global Task Team on the Implications of Climate Change on Coral Reefs. This

team of about a dozen coral reef experts from around the world had two tasks: to select the basic methods and protocols to monitor reefs; and report on the implications of global climate change for reefs. The methods chosen were developed during the ASEAN-Australia Living Coastal Resources project between 1984 and 1994 (see English, Wilkinson and Baker in Suggested Reading) as the basis for government level monitoring. These include the manta-tow method, which involves towing a diver behind a boat for a series of two-minute intervals to obtain a broad perspective, and a series of transect tapes laid on the reef to assess categories of the bottom (as easily recognised life-forms) and counts of fish, particularly those targeted by fishermen.

The International Coral Reef Initiative (ICRI) was launched at the UN Small Islands Developing States conference in Barbados in 1994, and held its first major meeting in Dumaguete, Philippines, in mid-1995. The 35 countries present developed 'The Call to Action' and 'The Framework for Action', which included increased coral reef monitoring, and asked the sponsors of the Global Task Team to take up the challenge. Thus the GCRMN was set up under the sponsorship of IOC/UNESCO, UNEP and IUCN, with the World Bank joining as a sponsor in 1998. The GCRMN is based at AIMS (Australian Institute of Marine Science) and ICLARM (International Center for Living Aquatic Resources Management, Manila), and has a broadly-based Scientific and Technical Advisory Committee to provide science and management advice. ReefBase, the global coral reef database in ICLARM is the end repository for the data. The GCRMN is also a contributor of coral reef data to the Global Ocean Observing System (GOOS).

The GCRMN will function as a network of independent Regional Nodes that will coordinate training, monitoring, and databases within participating countries and institutes in regions based on the UNEP Regional Seas Programme: Middle East; Western Indian Ocean and Eastern Africa; South Asia; East Asian Seas; Pacific; and Caribbean and Tropical Americas.
An important innovation was the decision of GCRMN and Reef Check to join forces in 1998 to expand the network of monitoring of coral reefs throughout the world. There is a natural division of emphasis: the GCRMN focusses on government level monitoring; whereas Reef Check targets community and volunteer monitoring. The union was made easy because both projects use compatible methods and send their data to ReefBase.

WHAT HAS THE GCRMN ACHIEVED?

One Node is functioning in South Asia, funded by the UK, with the governments of India, the Maldives, and Sri Lanka giving strong support. Training has been ongoing and the participants have been gathering data on the status of reefs, particularly after the severe

bleaching event that started in April. This Node is also playing a key role in the development of a manual for assessing socioeconomic parameters based on existing systems developed by UNEP, ICLARM and the University of Rhode Island (USA) for coastal communities. Another Node is functioning in the South Indian Ocean with assistance from the Indian Ocean Commission and the European Union, involving Comores, Madagascar, Mauritius, Réunion, and the Seychelles. Initial training has been completed, and reef monitoring has started at designated national sites. The countries of the East African coast have agreed to cooperate in reef monitoring and a funding proposal has been submitted by the Kenyan government to Sweden.

Monitoring training has been conducted in the Pacific, coordinated by SPREP, in the Cook Islands, Saipan, Tonga, Palau, Papua New Guinea, and Pohnpei, initially with trainers from the Australian Institute of Marine Science, but now the trainees are the trainers. The Pacific countries are enthusiastic supporters, largely because of a successful Pacific Year of the Coral Reef campaign conducted by SPREP. The countries have agreed on the composition and hosts of six nodes for the whole Pacific. The government of Hawaii is formulating plans for monitoring involving both scientific and community level participants.

Countries in southeast Asia are continuing the monitoring that they first started in the mid-1980s and now Vietnam, Cambodia, and Burma will participate in training funded by Japan, which is itself building a large coral reef conservation centre. There is considerable ongoing monitoring in the Caribbean, and this will expand with the help of the UNEP offices and the Caribbean database in Jamaica. Initiatives by the World Bank and Mexican government are important catalysts towards improving monitoring and management of Central American reefs.

Finally, this booklet is a product of the GCRMN and incorporates data and information assembled by GCRMN, Reef Check and other experienced coral reef experts. Our goal is to use this as the baseline to judge our performance and we aim to update the information every two years.

Clive Wilkinson is the Coordinator of the Global Coral Reef Monitoring Network, based at the Australian Institute of Marine Science, in Townsville (e-mail: c.wilkinson@aims.gov.au), and Bernard Salvat is Chair of GCRMN Scientific and Technical Advisory Committee, based at the University of Perpignan in France (e-mail: bsalvat@univ-perp.fr).

Suggested Reading

The following are some useful references to follow up the material presented in the essays above.

The bulk of the essays were drawn from papers presented at the 8th International Coral Reef Symposium, held in Panama City, June 1996 and published in Volume 1 of the Proceedings. The reference for these essays is:

Lessios, H.A. and Macintyre, I.E. (eds) (1997). Proceedings of the 8th International Coral Reef Symposium, Panama, June 24-29 1996, Volume 1. Smithsonian Tropical Research Institute, Balboa, Panama.

Other useful material:

Birkeland, C. (1997). Life and Death of Coral Reefs. Chapman & Hall, New York, 536pp.

Birkeland, C. (1997). Symbiosis, fisheries and economic development on coral reefs. Trends in Ecology and Evolution 12:364-367.

Bryant, D., Burke, L., McManus, J. and Spalding, M. (1997). Reefs at Risk: A Map-Based Indicator of Potential Threats to the World's Coral Reefs. World Resources Institute, Washington D.C, 56pp.

English, S., Wilkinson, C. and Baker, V. (1997). Survey Manual for Tropical Marine Resources. 2nd Edition. Australian Institute of Marine Science, Townsville, 390pp.

Ginsburg, R. N. (ed) (1993). Global Aspects of Coral Reefs: Health Hazards and History, 7-11 June 1993. University of Miami, Miami, 420pp. (This volume has a valuable series of papers on problems facing reefs around the world).

Hatziolos, M. E., Hooten, A. J. and Fodor, F. (1998). Coral Reefs: Challenges and Opportunities for Sustainable Management. In Proceedings of an associated event of the fifth annual World Bank Conference on Environmentally and Socially Sustainable Development. World Bank, Washington D.C., 224pp.

IOC/UNEP/IUCN. (1997). IOC/UNEP/IUCN Global Coral Reef Monitoring Network Strategic Plan. UNESCO, Paris, 10pp.

Jonannes, R. E. (1998). The case for data-less marine resource management : examples from tropical nearshore finfisheries. Trends in Ecology and Evolution 13:243-246.

Kelleher, G., Bleakley, C. and Wells, S. (1995). The Global Representative System of Marine Protected Areas. Volume II Wider Caribbean, West Africa and South Atlantic. Great Barrier Reef Marine Park Authority, Townsville ; World Bank, Washington D.C. ; World Conservation Union, Washington D.C., 93pp.

Kelleher, G., Bleakley, C. and Wells, S. (1995). The Global Representative System of Marine Protected Areas. Volume III Central Indian Ocean, Arabian Seas, East Africa and East Asia Seas. Great Barrier Reef Marine Park Authority, Townsville ; World Bank, Washington D.C. ; World Conservation Union, Washington D.C., 147pp.

Kelleher, G., Bleakley, C. and Wells, S. (1995). The Global Representative System of Marine Protected Areas. Volume IV South Pacific, Northeast Pacific, Southeast Pacific and Australia/New Zealand. Great Barrier Reef Marine Park Authority, Townsville ; World Bank, Washington D.C. ; World Conservation Union, Washington D.C., 212pp.

Maragos. J. E., Crosby, M. P. and McManus, J. W. (1996) Coral reefs and biodiversity: a critical and threatened relationship. Oceanography 9:83-99.

Oliver, J., De'ath, G., Done, T., Williams, D., Furnas, M. and Moran, P. (eds) (1995) Long-term monitoring of the Great Barrier Reef. Status Report Number 1. Australian Institute of Marine Science, Townsville, 121pp.

Salvat, B. (ed) (1987). Human impacts on coral reefs: facts and recommendations. Antenne Museum E.P.H.E, French Polynesia, 253pp.

Sheppard, C. R. C. and Sheppard, A. L. S. (1991). Corals and Coral Communities of Arabia. Fauna of Saudi Arabia 12.

Sudara, S., Wilkinson, C. R. and Chou, L. M. (eds) (1994). Proceedings of the Third Asean-Australia Symposium on Living Coastal Resources. Volume 2: Research Papers. Australian Institute of Marine Science, Townsville, 720pp.

Sweatman, H. (ed) (1997). Long-term monitoring of the Great Barrier Reef. Status Report Number 2. Australian Institute of Marine Science, Townsville, 161pp.

Wachenfeld, D., Oliver, J. and Davis, K. (eds) (1997). State of the Great Barrier Reef World Heritage Area Workshop. In Proceedings of a technical workshop held in Townsville, Qld, 27-29 November 1992. (GBRMPA Workshop Series 23). Great Barrier Reef Marine Park Authority, Townsville, 561pp.

Wachenfeld, D., Oliver, J. and Morrissey, J. I. (eds) (1998). State of the Great Barrier Reef World Heritage Area 1998. Great Barrier Reef Marine Park Authority, Townsville, 138pp.

Wells, S. and Hanna, N. (1992). The Greenpeace Book of Coral Reefs. Sterling Publishing Co., New York, 160pp.

Wells, S.M. (ed) (1988). Coral Reefs of the World. Volume 1: Atlantic and Eastern Pacific. UNEP, Nairobi ; International Union for Conservation of Nature and Natural Resources, Switzerland.

Wells, S.M. (ed) (1988). Coral Reefs of the World. Volume 2: Indian Ocean, Red Sea, and Gulf. UNEP, Nairobi ; International Union for Conservation of Nature and Natural Resources, Switzerland.

Wells, S.M. (ed) (1988). Coral Reefs of the World. Volume 3: Central and western Pacific. UNEP, Nairobi ; International Union for Conservation of Nature and Natural Resources, Switzerland.

Wilkinson, C. R. (1993). Coral reefs of the world are facing widespread devastation: can we prevent this through sustainable management practices? In Proceedings of the seventh International Coral Reef Symposium: Guam, Micronesia, 22-27 June 1992. Mangilao, University of Guam Marine Laboratory.

Wilkinson, C. R. (ed) (1994). Living Coastal Resources of South-east Asia: Status and Management: Report of the Consultative Forum, Third Asean-Australia Symposium on Living Coastal Resources, 1994. Australian Institute of Marine Science on behalf of the ASEAN-Australia Marine Science Project: Living Coastal Resources, Townsville, 133pp.

Wilkinson, C. R. and Buddemeier, R. W. (1994). Global Climate Change and Coral Reefs: Implications for People and Reefs. Report of the UNEP-IOC-ASPEI-IUCN Global Task Team on Coral Reefs. IUCN, Gland, 124pp.

Wilkinson, C. R., Sudara, S. and Chou, L. M. (eds) (1994). Living coastal resources of South-east Asia : status and review, Third Asean-Australia Symposium on Living Coastal Resources, 1994. Volume 1: Status Reviews. Australian Institute of Marine Science on behalf of the ASEAN-Australia Marine Science Project: Living Coastal Resources, Townsville, 454pp.

Woodley, J. D. (1995). Tropical American regional report on the issues and activities associated with coral reefs and related ecosystems. Prepared for the 1995 International Coral Reef Initiative Workshop, Dumague City, Philippines, May 1995, unpublished, 64pp.

List of Acronyms

AGRA	Atlantic and Gulf Reef Assessment
AIMS	Australian Institute of Marine Science
ASEAN	Association of South East Asian Nations
BS	Bird Sanctuary
CARICOMP	Caribbean Coastal Marine Productivity Program
CITES	Convention on International Trade in Endangered Species of Wild Flora and Fauna
COCCYTAC	Comite Cunsultor Cientifico y Tecnico de los Arrecifes Coralinos
COREMAP	Coral Reef Rehabilitation and Management Project
CRIOBE	Centre de Recherches Insulaires et Observatoir de l'Environnement
EIA	Environmental impact assessment
EPHE	Ecole Pratique des Hautes Etudes
EVAAM	Etablissement pour la Valorisation des Activités Aquacoles et Maritimes
FSM	Federated States of Micronesia
GBR	Great Barrier Reef
GCRMN	Global Coral Reef Monitoring Network
GEF	Global Environment Facility (established within the World Bank)
GOOS	Global Ocean Observing System
ICLARM	International Center for Living Aquatic Resources Management
ICM	Integrated Coastal Management (also IC Zone M and IC Area M)
ICRI	International Coral Reef Initiative
IFREMER	Institut Francais de Recherche pour l'Exploitation de la Mer
INPARQUES	Venezuelan national parks body
INVEMAR	Instituto de Investigaciones Marinas y Costeras (Colombia)
IOC	Intergovernmental Oceanographic Commission
IUCN	World Conservation Union
KWS	Kenya Wildlife Service
MARNR	Venezuelan agency for managing national parks
MARPOL	The International Convention of the Prevention of Pollution from Ships

MBRI	Mesoamerican Barrier Reef Initiative
MBRS	Mesoamerican Barrier Reef System
MLCD	Marine Life Conservation District
MMR	Ministry of Marine Resources (Eritrea)
MPA	Marine protected area
NAWC	Northern area of the wider Caribbean
NHP	National Historic Park
NGO	Nongovernmental organisation
NOAA	National Oceanographic Atmospheric Administration
NP	National Park
NWR	National Wildlife Refuges (USA)
NWS	National Wildlife Service
ORI	Oceanographic Research Institute
ORSTOM	Office de Recherche Scientifique et Technologique d'Outre Mer
OISS	Offshore Island Seabird Sanctuaries
PERSGA	Regional Organization for the Conservation of the Environment of the Red Sea and Gulf of Aden
RAP	Rapid Assessment Protocol
RR	Recreational Reserve
RS	Reserve Specials
SACEP	South Asia Cooperative Environment Programme
SAP	Strategic Action Program
SAREC	Swedish Agency for Research Cooperation (with Developing Countries)
SCUBA	Self-contained underwater breathing apparatus
Sida	Swedish International Development Agency
SP	State Park
SPREP	South Pacific Regional Environment Programme
TR	Territorial Reserve
WCMC	World Conservation Monitoring Centre
WIO	Western Indian Ocean
WWF	Worldwide Fund for Nature
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational and Scientific Organisation
UNDP	United Nations Development Program
USAID	United States Agency for International Development

Sponsoring Organisations

Australian Institute of Marine Science (AIMS)

The Australian Institute of Marine Science is recognised as a world leader in marine science research, with an emphasis on the study of tropical, coastal, estuarine, and shallow water processes.

AIMS was established by the Australian Commonwealth government in 1972 in order to manage Australia's marine environment and marine resources. Its purpose is to generate the knowledge to support the sustainable use and protection of the marine environment through innovative, world-class scientific and technological research.

Tel: +61 07 4753 4444
Fax: +61 07 4772 5852
Web site: http://www.aims.gov.au

Coastal Resources Center, University of Rhode Island (USA)

The Coastal Resources Center at the University of Rhode Island is dedicated to advancing coastal management worldwide. In addition to assisting in the development and implementation of coastal management programs in Rhode Island and the United States, the Center is active in countries throughout the world promoting the sustainable use of coastal resources for the benefit of all. Implementing coastal management projects in the field, building capacity through education and training, and sharing lessons learned and information throughout the coastal community are the foundation of the Coastal Resources Center's work. The Center has been an active participant in the International Coral Reef Initiative since its inception in 1994.

Tel: +1 401 874-6224
E-Mail: cyoung@gso.uri.edu
Web site: http://crc.uri.edu

CORAL - The Coral Reef Alliance

CORAL is a member-supported, non-profit organization based in California that works with the dive community and others to promote coral reef conservation around the world. CORAL is creating a new constituency for coral reef conservation by building support from divers, snorkellers, and other concerned individuals. CORAL supports community-based organizations by providing financial and technical support for coral reef conservation in communities throughout the world. In addition, CORAL builds public awareness about coral reefs through various education programs. CORAL's mission is to keep coral reefs alive.

E-mail: Coralmail@aol.com
Web site: http://www.coral.org/

EPHE - Fondation Naturalia Polynesia

The Ecole Pratique des Hautes Etudes (EPHE) is a French scientific institution for post-graduate study and research with centres in various universities. One team working in the University of Perpignan and in French Polynesia specialises in coral reef studies of both the reefs, and resources such as fisheries. It works in association with the Centre National de la Recherche Scientifique (CNRS) and has an active field station on the Island of Moorea. The Fondation Naturalia Polynesia is a private organisation that supports scientific activities in French Polynesia, particularly the EPHE Research Station in Moorea. A special theme is supporting reef research that will be the basis for reef conservation.

Tel: +33 4 6866 2055
Fax: +33 4 6850 3686
E- mail: bsalvat@univ-perp.fr

International Center for Living Aquatic Resources Management (ICLARM)

ICLARM is an autonomous, non-profit NGO with a charter of international research devoted to improving the productivity, management and conservation of aquatic resources for the benefit of users and consumers in developing countries. ICLARM is based in Manila, Philippines and is a partner in the Consultative Group on International Agricultural Research (CGIAR) focussing on fisheries and other living aquatic resources in three ecosystems, inland waterways, coastal areas and coral reefs. ICLARM has developed ReefBase, an international database of coral reef resources and is also a co-host of the GCRMN.

Tel: +63 2 812 8641 or 818 0466
Fax: +63 2 816 3183
E-mail: iclarm@cgiar.org
Web site: http://www.cgiar.org./iclarm/

IOC-UNESCO

The Intergovernmental Oceanographic Commission (IOC) in Paris has promoted marine scientific investigations and related ocean services for more than 30 years, with a view to learning more about ocean resources, their nature and sustainability. IOC, with United Nations Environment Programme (UNEP), World Conservation Union (IUCN), and the World Meteorological Organization, formed the Global Task Team on Coral Reefs in 1991 to select methods and develop plans to monitor the world's coral reefs. This Task Team was the immediate precursor to the Global Coral Reef Monitoring Network (GCRMN), and after the ICRI Dumaguete meeting in 1995, the IOC, UNEP and IUCN were invited to co-sponsor the GCRMN, with the World Bank joining as a co-sponsor in 1998. The GCRMN is coordinated and administered through the IOC and is a part of the Global Ocean Observing System, to which it contributes data on coral reef health and resources.

Tel: +33 1 45 68 41 89
Fax: +33 1 45 68 58 12
Web site: http://ioc.unesco.org/goos

Sida and SAREC

Sida, the Swedish International Development Cooperation Agency, and its Department for Research Cooperation (SAREC), assist developing countries alleviate poverty and achieve sustainable development. Environmental aspects are integrated in all development cooperation programs to ensure compliance with Agenda 21 and other environmental conventions. The Marine Science Program has actively promoted research cooperation and capacity for Integrated Coastal Zone Management in eastern Africa and the western Indian Ocean as well as in the southeast Asia region. The program is supporting many coastal projects and regional workshops and assisted in the development of the Western Indian Ocean Marine Science Association (WIOMSA) to enhance scientific capacity in the region. Sida is the main supporter of The Coastal Management Center in Manila and the Secretariat for Eastern African Coastal Area Management (SEACAM) which was set up to assist the countries of the region implement the Arusha Resolution (1993) and the Seychelles Statement (1996) on Integrated Coastal Zone Management in east Africa and the western Indian Ocean. Sida is currently developing projects to assist countries assess the significant level of coral bleaching and mortality throughout the western Indian Ocean.

Tel: +46 8 698 5000
Fax: +46 8 20 88 64
Web site: http://www.sida.se

World Bank — Environment

The World Bank is an International Financial Institution dedicated to the alleviation of poverty and improving the standard of living of developing countries around the world. The Bank seeks to do this through a combination of loans and technical assistance designed to stimulate economic growth within a context of environmental and social sustainability. As part of its expanding portfolio in environment and natural resources management, the Bank is supporting an increasing number of coastal and marine biodiversity conservation projects, particularly in partnership with the Global Environment Facility, bilateral donors and NGOs. The Bank's support for coral reef conservation has grown since its partnership with IUCN and the Great Barrier Reef Marine Park Authority to the produce the Global Representative System of Marine Protected Areas report in 1995 and its participation in the launch of the International Coral Reef Initiative later that year. The Bank is now involved in projects promoting the conservation and sustainable use of coral reefs in all major reef regions of the world, including the Middle East, the Western Indian Ocean, South Asia, East-Asia Pacific, and the Western Caribbean (with the Mesoamerican Barrier Reef Initiative).

World Bank — Special Programs

Under its new Vice-President for Special Programs, Ismail Serageldin, the World Bank is expanding its partnerships in the area of water resources management, strengthening links both upstream and downstream for improved water resource use, through support for initiatives like the Global Water Partnership and the World Commission on Water for the 21st Century, as well as support for coastal and marine-based knowledge creation and networking through ICLARM, CoralBase and the GCRMN. The Bank is based in Washington, DC, USA.

Tel: +1 202 458 5779
Fax: +1 202 477 0568
E-mail: Mhatziolos@worldbank.org