



GLOBAL CORAL REEF  
MONITORING NETWORK

STATUS OF  
CORAL REEFS  
OF THE WORLD:  
2004

VOLUME 1

EDITED BY CLIVE WILKINSON



Australian Government



AUSTRALIAN INSTITUTE  
OF MARINE SCIENCE

## **Dedication**

This book is dedicated to those people around the world who monitor coral reefs and assist in their conservation. Often they do this voluntarily because of a sincere wish to save these magnificent ecosystems. The book is also dedicated to the International Coral Reef Initiative and partners, the Management Group of the GCRMN, and the Australian Government acting through the Australian Institute of Marine Science. A particular dedication is to the Government of the USA, which has provided considerable support and encouragement to the GCRMN through the Department of State, the US National Oceanographic and Atmospheric Administration and Ruth Kelty.

Front Cover: Madang, Papua New Guinea- *Amphiprion percula* (Photo Courtesy of Dr. Gerald Allen, Tropical Reef Research);

Back Cover: Christopher McClelland © 2004

Maps were provided by UNEP-WCMC through ReefBase, The World Fish Center and we thank Nasir bin Nayan for their current format.

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## FOREWORD

Coral reefs fascinate people because of their unparalleled beauty and biodiversity. But coral reefs are probably the most endangered marine ecosystem on earth. Nearly 500 million people depend on coral reefs for food, coastal protection, cultural items, and tourism income; probably 30 million of the poorest people depend entirely on coral reefs for food. Unfortunately most coral reefs around the world are over-exploited and damaged by pollution, excess sediment and inappropriate development. Coral reef scientists predict massive destruction of coral reefs in the next decades because of increasing global climate change. Their loss will destroy the social fabric of many coastal communities and ruin a massive tourism industry that supports many tropical countries.

Coral reefs are especially important for some of the smallest and most vulnerable countries in the world. Many Small Island Developing States (SIDS) have few resources other than coral reefs. SIDS include countries that are totally made up of coral reefs and rest only a few metres above rising sea levels. For these countries, ecotourism based on healthy coral reefs offer the best chance to develop sustainable economies. Tourism – it is to be noted - is the fastest growing major industry in the world and ecotourism is growing at 10 to 30% per year and accounts for 20% of world-wide tourism.

The *Status of Coral Reefs of the World: 2004* report documents how human activities continue to be the primary cause of the global coral reef crisis. The report details many new initiatives aimed at reversing this degradation such as by conserving the biodiversity, the economic value and beauty of coral reefs. The report recognises that the major stresses to coral reefs are: natural forces that they have coped with for millions of years; direct human pressures, including sediment and nutrient pollution from the land, over-exploitation and damaging fishing practices, engineering modification of shorelines; and the global threats of climate change causing coral bleaching, rising sea levels and potentially threatening the ability of corals to form skeletons in more acid waters. If reefs are to survive as our natural heritage, we need to act locally to reduce direct human impacts and, globally, to combat greenhouse emissions.

This report, written by the Global Coral Reef Monitoring Network, and the International Coral Reef Initiative, contains the recommendations and requests from over 80 countries to conserve and manage their coral reef resources. Specifically, we ask for assistance to help conserve coral reefs for our countries and the world. Assistance is needed to: reduce the damage from coastal development, poorly planned coastal tourism and land-based sources of pollution on coral reefs; develop mechanisms of managing coral reef fisheries to ensure they are sustainable; and help control the unreported and illegal trade in coral reef and associated species.

The World Summit on Sustainable Development in Johannesburg in 2002 recognised that small countries needed assistance to: adopt integrated approaches to watershed, coastal and marine management; recognise traditional knowledge and management methods; increase the involvement of communities and the private sector in managing coral reefs; improve their capacity to monitor, conserve and sustainably manage coral reefs and associated ecosystems; and create representative networks of marine protected areas for the conservation and management of coral reefs, mangrove forests and seagrass areas.

We urgently need help to:

- develop more and larger Marine Protected Areas as larval reseeding grounds;
- stop destructive fishing and reduce fishing pressure on reefs;
- improve coastal land management by working with communities to reduce sedimentation;
- to reduce greenhouse gas emissions that are driving global climate change and threaten all coral reefs, especially those on SIDS;
- support community involvement in the fight to reverse the global coral reef crisis.

Some solutions to the coral reef crisis are relatively inexpensive; others will take time and considerable effort. We are convinced that with improved commitment, collaboration, cooperation and communication, future generations will be able to enjoy the beauty and benefits of the world's tropical and cold water coral reefs. We hereby endorse this *Status of Coral Reefs of the World: 2004* report and ask for your urgent assistance.



Tommy E. Remengesau,  
Jr. President of the Republic of Palau



H.E. James Alix Michel  
President of the Republic of Seychelles



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The Node Coordinators for all of the 17 GCRMN regions are listed at the end of the chapters, and in the GCRMN summary of the Sponsoring Organisations. These people keep the GCRMN going between these Status reports. I also wish to thank Posa Skelton, Robin South, Ian Miller and Carden Wallace for their careful editorial contributions. Jeremy Goldberg deserves special thanks as he emailed contributors, edited and drafted many pages, and created a sense of calm and organisation. I owe staff at AIMS special thanks. This book was prepared under an extremely tight schedule and was put into the final format by a very professional and friendly team at Science Communication at AIMS: Steve Clarke, Wendy Ellery, Kerie Hull, and Tim Simmonds – a special thank you.

The GCRMN has 5 partners who direct the network: Gregor Hodgson directs the Reef Check network and volunteers; Jamie Oliver organises the platform of ReefBase to make GCRMN data and information available to the world; Olof Linden directs the CORDIO program that supports monitoring in the Indian Ocean; Leah Bunce coordinates the socio-economic component of the GCRMN from NOAA; and Laretta Burke directs the Reefs at Risk project that provided valuable data on the Caribbean. The co-sponsors of the GCRMN have provided substantial assistance, advice and support: Intergovernmental Oceanographic Commission of UNESCO; United Nations Environment Programme (UNEP); IUCN - The World Conservation Union; The World Bank; Convention on Biological Diversity; AIMS; The WorldFish Center; and the ICRI Secretariat. The Management Group meets voluntarily at ICRI meetings to provide guidance

to the GCRMN. Direction for the GCRMN Management Group has been provided Carl Gustaf Lundin (Chair) and Kristin Sherwood of IUCN - I wish to thank them all.

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## CO-SPONSORS AND SUPPORTERS OF GCRMN

### **GCRMN Management Group**

IOC-UNESCO – Intergovernmental Oceanographic Commission of UNESCO, Paris  
UNEP – United Nations Environment Programme, Cambridge & Nairobi  
IUCN – The World Conservation Union (Chair), Gland, Switzerland  
The World Bank, Environment Department, Washington, DC, USA  
Convention on Biological Diversity, Secretariat, Montreal, Canada  
AIMS – Australian Institute of Marine Science, Townsville, Australia  
WorldFish Center, and ReefBase, Penang, Malaysia  
ICRI Secretariat – Governments of UK and Seychelles, London UK.

### **GCRMN Operational Partners**

Reef Check Foundation, Los Angeles, USA  
ReefBase, WorldFish Center, Penang, Malaysia  
CORDIO – Coral Reef Degradation in the Indian Ocean project, Sweden  
World Resources Institute, Washington DC, USA  
NOAA – Socioeconomic assessment group, Silver Springs, MD, USA

### **Major Financial Supporters of the GCRMN**

The Government of the USA, through the US Department of State and NOAA – National Oceanographic and Atmospheric Administration  
AIMS – Australian Institute of Marine Science, Townsville, Australia  
UNEP – United Nations Environment Programme via USA counterpart funds.

### **Financial Supporters of Status of Coral Reefs of the World: 2004**

Sida – Swedish International Development Cooperation Agency and Department for Research Cooperation (SAREC) Stockholm, Sweden  
US Department of State, Washington DC, USA  
NOAA – National Oceanographic and Atmospheric Administration, Silver Springs, USA  
Ministry of Foreign Affairs and Ministry of the Environment, Government of Norway  
The World Bank, Environment Department, Washington DC, USA  
ICRAN – International Coral Reef Action Network, Cambridge, UK  
IUCN – The World Conservation Union, Gland, Switzerland  
WWF – World Wildlife Fund, Washington DC & World Wide Fund for Nature, Europe  
TNC – The Nature Conservancy, Washington DC, USA  
CI – Conservation International, Washington DC, USA  
ICRI Secretariat – Governments of UK and Seychelles, London, UK  
CRC Reef - Cooperative Research Centre for the Great Barrier Reef, Townsville, Australia  
Total Corporate Foundation (Fondation d'Entreprise Total), Paris, France  
IFRECOR – The French Coral Reef Initiative, Paris, France  
Nature Conservation Bureau, Ministry of the Environment, Tokyo, Japan  
UNEP – Regional Seas, and GPA Coordination Office, The Hague, The Netherlands

### **Hosts of the GCRMN**

AIMS – Australian Institute of Marine Science, Townsville, Australia  
ReefBase at WorldFish Center, Penang, Malaysia  
CRC Reef - Cooperative Research Centre for the Great Barrier Reef, Townsville, Australia  
IMPAC- International Marine Project Activities Centre Ltd., Townsville, Australia



## INTRODUCTION

We, the undersigned, represent thousands of people in eight organisations working on research, management, conservation and the sustainable use of coral reefs around the world. Collectively we form the Management Group of the GCRMN and are pleased to endorse the *Status of Coral Reefs of the World: 2004* report.

The 2002 World Summit on Sustainable Development in Johannesburg confirmed that global sustainable development and poverty reduction requires a healthier and more sustainably managed ocean. WSSD paid special attention to coral reefs, which are critical for many countries, especially the Small Island Developing States. WSSD recommended that to sustain coral reefs will require integrated coastal and watershed management, the establishment of networks of marine protected areas, and the necessary institutional capacity building to foster these management approaches and help deliver them on the ground. Similar requests were made at the IUCN World Parks Congress in Durban in 2003. These are tasks for the international coral reef community; our organizations strongly support these goals and are actively contributing towards their achievement.

The Status reports of 1998, 2000, 2002 and now 2004 have become the benchmark in reporting on the global status of the world's coral reefs and emphasising the progress in conservation and management. Unfortunately, these reports also highlight the declining status of many coral reefs and losses of their invaluable resources. The reports also illustrate many new initiatives aimed at improved reef research, management and conservation. The declines are occurring, despite the major efforts by our agencies and many others to conserve coral reefs; therefore we request the assistance of the international community to expand our conservation efforts.

We firmly believe that the concerted efforts of the global community can halt and even reverse the decline in the world's coral reefs. There is a continuing decline in coral reefs adjacent to the large human populations in Eastern Africa, South, Southeast and East Asia, and the Caribbean. However, the situation is not hopeless, and most remote reefs remain healthy. The Status 2000 report indicated that approximately 16% of the world's coral reefs had been effectively destroyed through unprecedented coral bleaching during the major El Niño/La Niña shifts in the global climate in 1997-98. Since then approximately half of these reefs are showing encouraging rates of recovery, especially those in well managed Marine Protected Areas and No-Take Reserves, or remote from human stresses. This illustrates the inherent recovery capacity of coral reefs; provided that the major human pressures of sediment and nutrient pollution from the land, over-fishing and especially destructive fishing, and engineering developments are removed or controlled. We anticipate that these reefs will continue to recover, with one proviso - that there is not a repeat in the next decade of major climate shifts like those of 1997-98. Sadly,

many predictions from coral reef scientists and the IPCC (Intergovernmental Panel on Climate Change) do not give cause for such optimism.

Our agencies also support the International Coral Reef Initiative (ICRI) that brings the major coral reef stakeholders together to set the agenda for coral reef conservation. These stakeholders assist us in setting the agenda on actions required to conserve coral reefs. These actions include the following:

- Using Integrated Coastal Management (ICM) to reduce land based sources of pollution from poor land use practices that deliver excess sediments and nutrients onto coral reefs e.g. from deforestation, unsustainable agriculture, untreated domestic and industrial wastes;
- Reducing or diverting fishing effort to avoid over-exploitation and specifically stopping destructive practices such as bomb and cyanide fishing;
- Developing interconnected networks of MPAs to support the effective flow of larvae from coral reefs and the maintenance of vital ecosystem processes;
- Ensuring that the current MPAs are effectively managed with adequate financial, logistic and, especially, human resources;
- Focussing on developing MPAs that have higher resilience and resistance to global threats, such as coral bleaching and disease and also protecting reefs with healthy and reproducing populations of coral reef species;
- Developing alternative livelihoods for coastal communities to reduce the need to exploit reef resources e.g. ecotourism, sustainable aquaculture of food and aquarium species, more effective agriculture, community industries based on traditional cultures;
- Expanding research and monitoring capacity in more countries, especially small developing states, and undertaking the fundamental research needed for sound and adaptive management of coral reefs; and
- Improving the capacity of governments and NGOs for monitoring, enforcement and surveillance in support of coral reef management and implementing integrated oceans governance.

This report contains the recommendations from more than 80 countries for specific actions to halt the decline in coral reef destruction and suggests means for donors to assist in coral reef conservation. We welcome the chapter in this report on cold water coral reefs; this helps focus attention on these largely ignored, high diversity ecosystems.

In our agencies, we recognise the need to expand the skills and discipline base for improved coral reef conservation. There are many natural scientists active in coral reef research, monitoring and advocacy, but we lack the input and ideas from other disciplines such as from the social sciences, economics and business management, law and policy development to ensure better uses of human and financial resources. A critical gap is in socio-economic assessment and monitoring, and the development of public-private partnerships. The GCRMN and partners have made great progress in ecological monitoring; however there has been insufficient progress in monitoring how people interact with reefs, although the GCRMN has produced a socioeconomic Manual and guidebooks. We urge more countries and project agencies to implement socio-economic monitoring in parallel with the ecological monitoring.



There are many examples in this 4<sup>th</sup> edition of Status of Coral Reefs of the World of the assistance provided by monitoring for decision making in coral reef conservation. The reporting on World Heritage, Man and the Biosphere, Ramsar and International Coral Reef Action Network (ICRAN) Demonstration sites continues to show improvements in monitoring and reporting. However, there is an ongoing need to ensure that monitoring is meeting the needs of coral reef managers and that the information flows readily to the managers and user communities. This is the theme of partnerships between GCRMN, ReefBase (the global coral reef database), Reef Check (the community and volunteer monitoring specialists), the CORDIO program which is operating in the wider Indian Ocean, and other monitoring programs. The decision by the French Government to fund a major coral reef program in the Pacific Ocean is particularly welcome as it complements support from the USA, Canada and Japan. We encourage regional partnerships to assist developing countries with coral reef activities.

Coral reefs play a key role in the livelihoods of hundreds of millions of coastal dwelling poor people. Climate change and anthropogenic stress currently threaten the world's coral reefs, thereby undermining the livelihoods of large human populations. A significant target of the Millennium Development Goals is halving world poverty by 2015, and sound, integrated management of the environmental and social dimensions of coral reefs is critical. This will require strong oceans governance based on good science and accurate data. The IOC of UNESCO, with the World Meteorological Organization, UNEP, the International Council for Science and Food and Agriculture Organization established the Global Ocean Observing System (GOOS), with the GCRMN as a critical partner in providing data on coral reef changes associated with global climate change. Localised human stress also plays a major role in coral reef degradation and may actually undermine the resilience of coral reefs to disturbance events and accelerate environmental change associated with climate change. To understand these relationships and their implications for coral reef sustainability and the welfare of hundreds of millions of coastal dwelling poor who depend on them, IOC is collaborating with the World Bank and the Global Environment Facility on a major new targeted research project for coral reefs. The Project will put new knowledge and tools into the hands of decision-makers to build capacity for science-based management in countries where coral reefs occur and to enhance management effectiveness at the local, national and regional levels. Other key partners in this initiative are the University of Queensland, Australia and the US National Oceanic and Atmospheric Administration.

In addition to targeted investigations, there is an essential need for comprehensive, reliable and accessible data on the status of coral reefs and the goods and services they provide for people to achieve the goals for sustainable development outlined in international forums. UNEP (United Nations Environment Program), via the UNEP Coral Reef Unit, the Regional Seas Program and the Global Program of Action for the Protection of the Marine Environment from Land-based Activities, assists the GCRMN promote monitoring of coral reefs and user communities to improve the capture, flow and assessment of pertinent information, especially in developing countries and SIDS. The GCRMN is providing a baseline to measure success of our combined efforts to save coral reefs ecosystems and achieve sustainable development targets. This 'Status 2004' report warns us that many reefs are degrading or under threat, including the poorly known cold-water reefs. The extensive information in this report, compiled through an exemplary world-wide collaboration between organisations, governments and individuals, will guide our efforts to combat these threats effectively at global to local scales to conserve, manage and use coral reefs sustainably.

NGOs and government agencies play key roles in coral reef conservation; especially by passing monitoring information to the GCRMN. The IUCN - The World Conservation Union assists the GCRMN by catalysing and providing technical assistance to some of its 1035 governmental and non-governmental members across 181 countries that are active in coral reef monitoring and conservation. The IUCN assists the GCRMN broaden its influence and encourages and assists communities around the world in coral reef conservation. IUCN is continuing to build a marine program, with coral reefs and sponsorship of the GCRMN as major components. Other critical activities include developing effective MPAs, evaluating and protecting vulnerable coral reef and other marine species, and illustrating the links between global climate change and coral reefs. This is in collaboration with the Convention on Biological Diversity, and the 'Coral Reef Resilience Partnership'. IUCN is also strengthening collaboration with the Coral Reef Degradation in the Indian Ocean (CORDIO) program, and hosting the IUCN-CORDIO-GCRMN officer in the IUCN office in Sri Lanka.

There are 90 World Bank client countries with coral reefs as part of their natural capital. While some have achieved significant economic growth from coral reef related tourism and fisheries, a third of these countries are among the poorest in the world. Poverty can lead to coral reef degradation, from over-fishing and unsustainable land use. But effectively managed coral reefs, which generate a range of ecosystem goods and services, can help lift communities out of poverty. The Bank is committed to conserving these vital development resources and improving their management to ensure a sustainable flow of benefits to coastal communities and small island economies from healthy coral reefs. The Bank and the GEF, in partnership with governments and other donors, have invested hundreds of millions of dollars in countries to promote conservation and sustainable use of coral reefs. An essential part of this formula is good governance, involving shared ownership and responsibility for the resources among stakeholders; this requires reliable information about the health of reefs and incorporation of this knowledge into transparent decision-making. The World Bank will continue to support the GCRMN by incorporating GCRMN protocols for ecological and socio-economic monitoring into projects with active community participation. This, coupled with a new initiative for coral reef targeted research and capacity building, will link information and new technologies to improving management for the benefit of coral reefs and user communities.

Coral reefs are invaluable for the riches in biodiversity and essential resources for the sustainable livelihoods of many coastal communities. Because of their importance and vulnerability to human impacts, the Conference of the Parties to the Convention on Biological Diversity has consistently recognised them a major focus of its program of work on marine and coastal biological diversity. Ensuring healthy coral reefs for future generations is also a vital component of the CBD target to achieve by 2010 a significant reduction of the current rate of biodiversity loss at the global, regional and national level as a contribution to poverty alleviation and to the benefit of all life on earth. The information collected by the GCRMN provides a major contribution to measuring progress towards achieving this important target in the marine environment.

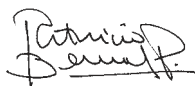
Coral reefs are coming under more and more pressures to provide fisheries resources as income and food for people in developing countries. The WorldFish Center has made coral reefs one of its focal areas in recognition of the importance of these roles and is working with other agencies to determine how MPAs can conserve fish stocks and increase productivity in adjacent

areas. The WorldFish Center encourages regular monitoring and the dissemination of status reports by researchers, governments and communities and has developed ReefBase to ensure that coral reef data and information are widely disseminated. ReefBase serves as the global database for the GCRMN and other monitoring networks, as well as being a central repository of coral reef information.

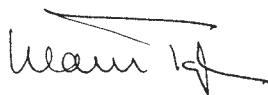
Coral reef monitoring is fundamental in Australia for the sustainable management of the Great Barrier Reef, the largest World Heritage Site in the world, as well as the reefs off Western and northern Australia. It is recognised that these reefs are under much lower pressures than others in the region. The Australian Institute of Marine Science maintains a program of regular monitoring on the eastern and western side of Australia to ensure that there is an early warning system of reef degradation. A new centre for tropical resource research is now being established in northern Australia in association with the Australian National University. AIMS also plays a fundamental role in developing monitoring methods and in displaying results of monitoring on the Internet, and continues to support global coordination of the GCRMN.

Since the creation of ICRI in 1994 and the adoption of the *Call to Action* and *Framework for Action*, ICRI has addressed many emerging issues, ranging from coral bleaching and trade in corals, and recently to threats to cold-water corals. The WSSD in 2002 pledged to “develop national, regional and international programs for halting the loss of marine biodiversity, including coral reefs and wetlands” and to “implement...the program of action called for by the International Coral Reef Initiative to strengthen joint management plans and international networking...including coral reefs”. This is a clear mandate to further raise awareness of the importance of coral reefs and press for action to better protect and manage them. ICRI is helping to implement WSSD committed themes on: well-managed MPAs; integrated coastal zone management; sustainable fishing; development and application of the ecosystem approach; and better oceans governance. ICRI will continue to provide an informal, global forum for coral reef stakeholders to initiate and support the implementation of internationally agreed commitments, goals and targets related to the conservation, protection and sustainable management of coral reefs and the livelihoods linked to them. In so doing, ICRI will continue to co-operate with and co-ordinate the activities of organisations within and outside the UN system, focus on a regional approach to coral reef work and liaise with the Regional Seas Conventions and Action Plans, make contact with donor agencies, increase government-level engagement, and encourage greater private sector participation.

While this Status report details continuing losses of coral reefs as a result of human activities, we are encouraged by the many new initiatives aimed at conserving the coral reef resources that many people depend on. We are collaborating with the GCRMN to improve the flow of information for improved coral reef conservation, and seek more collaboration and cooperation from individuals, governments and agencies to conserve coral reefs for future generations. The sharing of information is improving through the information superhighways, but many countries need assistance to catch up with the larger developed countries in gaining high speed access to the internet sources of information. We firmly believe that our cooperative efforts can make a huge difference. Therefore we commend this report to you as another step towards improved communication and coral reef conservation.




Patricio Bernal, Executive Secretary, Intergovernmental Oceanographic Commission of UNESCO



Klaus Toepfer, Executive Director, United Nations Environment Program



Carl Gustaf Lundin, Head, Global Marine Program, IUCN – The World Conservation Union & Chair, GCRMN Management Group



Warren Evans, Director, Environment Department, The World Bank



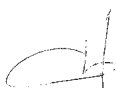
Hamdallah Zedan, Executive Secretary, Convention on Biological Diversity



Ian Poiner, Director, Australian Institute of Marine Science



Stephen Hall, Director General, WorldFish Center



Rolph Payet, Seychelles, Co-Chair, International Coral Reef Initiative Secretariat

# EXECUTIVE SUMMARY

CLIVE WILKINSON

## SYNOPSIS

The assessments of more than 240 contributors from 98 countries in this *Status of Coral Reefs of the World: 2004* report that:

### CURRENT STATUS OF CORAL REEFS

- Estimates in this report are that 20% of the world's coral reefs have been effectively destroyed and show no immediate prospects of recovery;
- Approximately 40% of the 16% of the world's reefs that were seriously damaged in 1998 are either recovering well or have recovered;
- The report predicts that 24% of the world's reefs are under imminent risk of collapse through human pressures; and a further 26% are under a longer term threat of collapse;
- Coral reefs around the world continue to decline from increasing human pressures; poor land management practices are releasing more sediment, nutrients and other pollutants that stress reefs;
- Over-fishing and particularly fishing with destructive methods are: threatening the normal functioning of coral reef ecosystems; reducing populations of key reef organisms; lowering coral reef productivity; and, along with pollution, shift the advantage towards macro-algae by removing grazing pressure. These algae smother and out-compete corals;
- Pressures on reefs from coral predators such as the crown-of-thorns starfish (COTS) and coral disease have not increased recently (sometimes because corals have declined); but severe problems remain on some reefs. There is evidence that these are exacerbated by human pressures, either by removing the predators of COTS and/or increasing water temperatures that stress corals, making them more susceptible to coral diseases;
- Analyses of coral reefs in the wider Caribbean region confirm major reef declines and they do not resemble the reefs of 30 years ago. Coral cover on many Caribbean reefs has declined by up to 80%; however there are some encouraging signs of recovery;

- There are few encouraging signs for reefs in the high biodiversity areas of Southeast Asia and the Indian Ocean, where human pressures continue to increase on coral reef; whereas reefs in the Pacific and around Australia remain quite healthy.

## **GLOBAL THREATS TO CORAL REEFS**

- Many coral reefs continue to recover after the 1998 El Niño/La Niña global coral bleaching event, with stronger recovery in well-managed and remote reefs; however, the recovery is not uniform and many reefs virtually destroyed in 1998 show minimal signs of recovery. This recovery could be reversed if the predicted increases in ocean temperatures occur as a result of increasing global climate change;
- There has been no recurrence of the major global-scale climate change pressures of 1998; although there have been some more localised bleaching events in 2000 and 2003 causing damage to reefs;
- The coral bleaching in 1998 was a 1 in a 1000-year event in many regions with no past history of such damage in official government records or in the memories of traditional cultures of the affected coral reef countries. Also very old corals around 1000 years old died during 1998. Increasing sea surface temperatures and CO<sub>2</sub> concentrations provide clear evidence of global climate change in the tropics, and current predictions are that the extreme events of 1998 will become more common in the next 50 years, i.e. massive global bleaching mortality will not be a 1/1000 year event in the future, but a regular event;
- Coral disease and major coral predators like the crown-of-thorns starfish continue to threaten reefs and evidence points to human disturbance as a contributing and catalytic factor behind these increases.

## **CORAL REEF MANAGEMENT, AWARENESS RAISING AND POLITICAL WILL**

- There was a major advance in the protection of the Great Barrier Reef with increases in the amount of no-take areas from 5% to 33%, following a careful analysis using the best available science and extensive consultation with major stakeholders;
- The World Summit on Sustainable Development in 2002 called for the establishment of networks of larger marine protected areas (MPAs) and a major international effort to reduce losses in biodiversity, including the biodiversity on tropical and cold-water coral reefs;
- Many coral reef countries lack the resources of trained personnel, equipment and finances to effectively conserve coral reefs, establish MPAs and enforce regulations;
- This lack of resources is often exacerbated by a poor awareness of the problems facing coral reefs and their significance in local economies, and inadequate political will to tackle difficult environmental problems;
- Major international NGOs are combining their expertise and resources to establish networks of MPAs and improve management capacity. A major focus is on the high biodiversity region of Southeast Asia and the Western Pacific;
- Some of these NGOs have developed rapid assessment methods to select sites for urgent protection and also designed tools to assist resource managers protect reefs from global change stresses;



*A summary of the current status of coral reefs in the 17 regions of the world designated as Nodes within the Global Coral Reef Monitoring Network (GCRMN). Experts from each region, as well as people with considerable experience provided the assessments. However, these assessments should be regarded as indicative, because there are insufficient coral reef monitoring data for many of these regions to make definitive statements on losses and authoritative predictions on the future.*

*The number of reefs in the destroyed column has increased from 11% in 2000, with the addition of more damaged reefs and those that have not recovered from 1998. It is apparent that about half of the reefs damaged in 1998 have recovered; but many have not.*

Region	Coral Reef Area km <sup>2</sup>	Destroyed Reefs (%)	Reefs recovered (%) / reefs destroyed in 1998 (%)	Reefs at Critical Stage (%)	Reefs at Threatened Stage (%)	Reefs at Low or No treat level (%)
4. Red Sea	17,640	4	2 / 4	2	10	84
5. The Gulfs	3,800	65	2 / 15	15	15	5
6. East Africa	6,800	12	22 / 31	23	25	40
7. SW Indian Oc.	5,270	22	20 / 41	36	31	11
8. South Asia	19,210	45	13 / 65	10	25	20
9. SE Asia	91,700	38	8 / 18	28	29	5
10. E & N Asia	5,400	14	3 / 10	23	12	51
11. Australia, PNG	62,800	2	1 / 3	3	15	80
12. SW Pacific Ids	27,060	3	8 / 10	18	40	40
13. Polynesian Ids	6,733	2	1 / 1	2	3	93
14. Micronesian Ids	12,700	8	1 / 2	3	5	85
15. Hawaiian Ids	1,180	1	NA	2	5	93
16. US Caribbean	3,040	16	NA	56	13	15
17. North Caribbean	9,800	5	3 / 4	9	30	56
18. Central America	4,630	10	NA	24	19	47
19. East Antilles	1,920	12	NA	67	17	4
20. S Trop America	5,120	15	NA	36	13	36
<b>TOTAL</b>	<b>284,803</b>	<b>20</b>	<b>6.4/16</b>	<b>24</b>	<b>26</b>	<b>30</b>

1. Coral reef area from the World Atlas of Coral Reefs (2001).
2. Reefs 'destroyed' with 90% of the corals lost and unlikely to recover soon;
3. Total of reefs recovered of the global coral bleaching losses in 1998 (%);
4. Reefs at a critical stage with 50% to 90% loss of corals and likely to join category 2 in 10 to 20 years;
5. Reefs threatened with moderate damage - 20 to 50% loss of corals and likely to join category 1 in 20 to 40 years;

NA. Not applicable, as there were no losses in 1998.

Categories 4 and 5 are based on the very high to high risk, and the medium risk categories of the Reefs at Risk process (Box p 460).

- International interest and political will for the protection of coral reefs is improving and the International Coral Reef Initiative is expanding to further catalyse improved management of coral reefs and raise the profile of all coral reefs within global forums;
- Cold water coral reefs are now being recognised as valuable resources that warrant protection from the massive degradation being caused to them by deep water trawling; and
- Millions of people around the world were made aware of coral reef conservation via the animated film on Nemo on the Great Barrier Reef; the film carried many coral reef conservation messages, but there were unfortunate consequences with an increase the trade of aquarium species and the release of some species in the wrong regions.

## THE EXECUTIVE SUMMARY

The Status 2004 report includes the recurring **Global Themes** of climate change, coral diseases and predators, anthropogenic pressures and inadequate governance of coral reefs with the particular focus on two **Regional Themes**: the wider Caribbean (including nearby Atlantic Ocean reefs); and the Great Barrier Reef of Australia, **Recommendations** from the 96 countries detailed in this report; and summaries of the status of coral reefs in 17 regions of the world.

The **Executive Summary** is structured with: a brief historical summary of reefs from 10,000 years ago to 2014; an examination of two special regions of the world where there have been major changes (the wider Caribbean and the Great Barrier Reef); a summary of the 'Top Ten' threats to the worlds coral reefs; new initiatives for the conservation of coral reefs; recommendations for remedial action; and summaries of coral reef status in the regions of the world, the GCRMN Nodes, from the following chapters.

**Coral Reefs in a Historical Perspective** –from 10,000 years ago to the present:

- The Distant Past, 10,000 years ago
- Status of reefs 1000 years ago
- Status of reefs 100 years ago
- 10 Years Ago in 1994

**Two Major Coral Reef Regions** –major changes in coral reef health and management in the last 2 years:

- Wider Caribbean
- Great Barrier Reef

**Threats and Stresses to Coral Reefs** - multiple pressures on coral reefs causing local to global damage:

- Global Climate Change
- Diseases, Plagues And Invasives
- Direct Human Pressures
- Poor Governance And Lack Of Political Will
- International Action or Inaction

**New Coral Reef Initiatives** – local to global initiatives aimed at arresting the decline in coral reefs

- Management Of Coral Reefs
- Science on Coral Reefs
- Rising Public Awareness Of Coral Reef Problems
- Recognition Of Cold Water Coral Reefs

**Recommendations for the Future of Coral Reefs**

- Action To Conserve Coral Reefs
- Action To Improve Oceans Governance

**Status of Coral Reefs of the World by Regions**

**Two Global Calls to Action**

- Okinawa Declaration, 2004 – from coral reef scientists;
- ITMEMS2 Action Statement – from coral reef managers.

## **CORAL REEFS IN A HISTORICAL PERSPECTIVE**

**The Distant Past, 10,000 years ago:** The history of modern coral reefs starts about 10,000 years ago at the end of the last ice age (in the Pleistocene) when sea levels were 110 to 120 meters below present levels. All previous coral reefs were limestone hills, probably covered in tropical and sub-tropical forests. There were major human migrations during low sea levels allowing access to new lands. Sea levels rose at about 240 cm per 100 years for 5,000 years (current predicted rate of sea level rise is approximately 50 cm per 100 years) and covered these limestone hills forming the base for modern coral reefs. These early human populations exploited coral reef the resources, and there is strong archaeological evidence of major harvesting of fishes, molluscs, dugongs, manatees and especially turtles in most areas. That rate of exploitation has exponentially increased as human populations grew and technology increased.

**Status of reefs 1000 years ago:** The major human migrations had occupied most coral reef areas, with the exception of some Indian Ocean islands or very remote islands and atolls. These peoples exploited coral reef resources for food and building materials. However, the reefs would have been regarded as mostly pristine by current standards with healthy corals, large, well-structured fish and invertebrate communities, with probably only a depletion of some of the larger fauna; turtles, dugong and giant clams in shallow water. These indigenous populations remained relatively small and, many of those on the smaller islands, were developing traditional management of coral reef resources to ensure sustainability.

**Status of reefs 100 years ago:** The consensus opinion of the 94 countries in the 17 ‘GCRMN’ regions is that their reefs were generally healthy 100 years ago with high coral cover and relatively ‘natural’ fish populations. Exploitation was increasing, but the harvesting of fishes and many invertebrates was within sustainable limits for the reefs. The exception was the large fauna; dugong, turtles and giant clams in shallow water. Pollution was not considered as a problem and there was little sediment damage, although the clearing of land in the tropics for agriculture was increasing. There was no concept of a ‘coral reef problem’ and little consideration of the need for management of the resources, except some like pearl shell in the Pacific.

**10 Years Ago in 1994:** This date was chosen because it marks the initiation of the International Coral Reef Initiative (ICRI) and the recommendation to form the Global Coral Reef Monitoring Network (GCRMN). These steps followed the Rio World Environmental Summit in 1992 and the 7<sup>th</sup> International Coral Reef Symposium, when the first alarming predictions on the future coral reefs were made. In 1993, there was a landmark conference in Miami that concluded that there was insufficient information to assess the status of the world's coral reefs. These were the catalysts for ICRI, the GCRMN (started in 1996) and Reef Check (in 1998). The alarm was raised of the global problem with coral reefs, with calls for urgent action to arrest the decline and implement effective conservation. The first Status of Coral Reefs of the World report was produced in 1998; essentially a summary of information presented at the 8<sup>th</sup> International Coral Reef Symposium in Panama.

**This Status of Coral Reefs of the World: 2004** details the status of the coral reefs and presents some cause for optimism and considerable reason for concern. This report recommends: urgent action to reduce the direct damage from human activities on coral reefs; a need to combat increasing global climate change that is directly and indirectly causing major coral reef decline and poses the major threat for most of the remaining healthy coral reefs; and the improvement of oceans governance and the capacity in small countries to implement effective and sustainable management of their coral reef resources. The optimistic opinion is that these actions will lead to effective coral reef conservation; the pessimistic opinion is that if the world continues in a 'business-as-usual' manner, then many of the coral reefs will cease to function and provide goods and services to millions of people and lose large resources of biodiversity.

## **TWO MAJOR CORAL REEF REGIONS: WIDER CARIBBEAN AND GREAT BARRIER REEF**

This reports focuses on two regions for diametrically opposing reasons:

- An example of **good news** - major initiatives to conserve and protect the Great Barrier Reef of Australia (GBR); and
- An example of **bad news** - with large-scale analyses showing significant and catastrophic degradation of coral reefs throughout the Wider Caribbean, with few encouraging signs.

### **Great Barrier Reef**

The major global initiative for coral reef conservation during the past 2 years was passed by the Parliament of Australia in early 2004, with the declaration of 33% of the whole province of the GBR (the GBR World Heritage Area) as highly protected status (or no-take zones). This is an increase from approximately 5% that was the case when the GBR was first zoned for protection in 1981. The argument for the increase was based on the conservation of the biodiversity components of all of the ecosystems ('ecoregions' or 'bioregions'), including seagrass beds, sandy and muddy bottoms and deep continental shelf slopes. This is in contrast to the previous zoning, and much of the reef protection around the world, where the focus has been just on the reefs.

The rezoning was considered necessary by the Australian government and the managing authority, the Great Barrier Reef Marine Park Authority (GBRMPA), when there was increasing scientific evidence that existing multiple-use zoning was inadequate to conserve the full range of biodiversity for the entire GBR. For example: dugong populations have declined by 97% since the 1960s; nesting loggerhead turtles declined by 50-80% over 4 decades; commercial

## REZONING THE GREAT BARRIER REEF

The most significant new initiative in coral reef conservation in the world since the Status report in 2002 has been the new Zoning Plan for the Great Barrier Reef Marine Park. More than 33% of the Marine Park is now protected by 'no-take' zones (called 'green' zones), with 'representative' examples of all broad-scale habitat types (71 bioregions) highly protected. This increase from less than 5% became Australian law on 1 July 2004. Prior to the rezoning, there were concerns that the highly protected areas were inadequate to ensure that the biodiversity of the Great Barrier Reef remained healthy, productive and resilient into the future. For example, target fish species were fewer and smaller on heavily fished reefs, with evidence that nearby trawling was removing juveniles.

The Australian Government recognised that the Great Barrier Reef had icon status with its inscription on the World Heritage List in 1981 and that it contributed more than USD1,000 million per year directly to the economies of coastal communities and the nation. Australians therefore have a strong responsibility for, and interest in, reef conservation. Between 1999 and 2004, the GBR Marine Park Authority undertook detailed planning (the Representative Areas Program) to upgrade the zoning for the Marine Park, with the primary aim of protecting the full range of biodiversity within the Great Barrier Reef. The original zoning had focused on the coral reefs and largely ignored the adjacent seagrass, mangroves, soft sediment and deep water areas. The new planning process, which included comprehensive scientific assessment and community involvement, recognised 70 bioregions within the Marine Park including areas of sandy and muddy bottoms, continental slopes and deep oceanic areas. No-take protection was extended to a minimum of 20% of each of the 70 bioregions, such that the Marine Park now includes protection for 33.3% (114,530 km<sup>2</sup>) in the world's largest network of highly protected areas. It also provides greater protection from a range of threats, including all forms of extraction. This was not achieved without some controversy and resistance, but community involvement and participatory processes involved more than 31,000 public submissions (Box p 325), combined with a strong national desire for greater protection of the Great Barrier Reef. The Government is providing assistance, which may include licence buy-outs for affected parties such as commercial fishers with reduced income earning potential as a result of the new zoning.

The strategy of protecting representative examples of all bioregions following wide consultation is now recognised as 'world's best practice', and is the most comprehensive and innovative global advance in marine conservation and the systematic protection of marine biodiversity in recent decades. Importantly, it recognises the value of the entire Great Barrier Reef ecosystem and will assist industry achieve increased levels of environmental and financial sustainability. The Representative Areas Program has 'raised the bar' for the level of protection required to conserve biodiversity and habitats, and is being observed closely by governments and agencies around the world. From Jon Day, GBRMPA, [jonday@gbbrmpa.gov.au](mailto:jonday@gbbrmpa.gov.au)

and recreational fishing has doubled since 1990 and populations of major target species of fishes were reduced and composed of smaller individuals; the annual flow of sediments and nutrients into the GBR has increased 4-fold; and the reefs have suffered from severe coral bleaching, a series of cyclones and outbreaks of COTS.

This increase is in considerable contrast to other parts of the world, where areas under high protection are much smaller. It must be emphasised that this high level of protection was achieved in Australia, which has a relatively small and wealthy population, without subsistence fishing pressures, however it was determined that the current rates of commercial and recreational fishing were threatening the diversity, especially trawling in inter-reef waters. Thus a benchmark or target has been established for other areas of the world to conserve their coral reefs.

### **The Wider Caribbean**

There has been a major and possibly catastrophic decline in the coral reefs of the wider Caribbean, including the reefs of the nearby Atlantic, with the estimated decline in live coral cover on many of the reefs from about 50% cover on many reefs just 25 years ago to about 10% on these reefs now. These declines are due to similar problems experienced in reefs around the world, with coral bleaching and disease particularly prominent, often coinciding with Hurricanes and the chronic problems of over-fishing, pollution with nutrients and sediments and coastal modification, dredging and mining of coral reefs. The major decline has been particularly evident in the formerly dominant and major reef building corals, the staghorn and elkhorn species (*Acropora cervicornis* and related species and hybrids, and *A. palmata*). These corals were devastated by a range of coral diseases and coral bleaching in the 1980s and 1990s such that there are recommendations that these species be listed as endangered under USA laws.

The only encouraging news is that there appears to be some recovery in the major reef building coral species in some parts of their range, with an apparent reduction in the incidence of disease, and a reduction in major recent bleaching events. However, this should not be interpreted as good news, as the severity and extent of coral bleaching appears to have been increasing over the past 20 years (below).

The prognosis, however, is not particularly encouraging for Caribbean reefs as human pressures continue to mount with increasing populations. There are currently 116 million people living within 100 km of a Caribbean coast, which is a 20% increase in the past 10 years. These pressures and the threats of global climate change pose a potential major threat for the future. Many of the reefs in the wider Caribbean are within the territorial waters of small developing states, with little capacity and few resources to implement effective management. Most reefs continue to be damaged by over-fishing such that surveys, especially by Reef Check and AGRRA, show that fish stocks are close to collapse throughout, with very few areas having populations of breeding fish. Moreover, there are very few areas with highly protected MPAs and most of those that do exist are not enforced.



## LISTING OF CARIBBEAN CORALS AS ENDANGERED SPECIES

Has the unthinkable happened? Could some of the most common coral species in the wider Caribbean be listed as endangered species? *Acropora palmata* (elkhorn coral), *A. cervicornis* (staghorn coral) and *A. prolifera* (fused-staghorn coral) were the dominant reef-building corals on reefs of Florida and throughout the Caribbean for the past half-million years. These species have suffered an 80 – 98% decline over the last 30 years throughout vast portions of their range, causing major losses in coral cover and opening space for other organisms to occupy. However, there are still some healthy stands of these corals, providing hope that recovery may be possible.

The Center for Biological Diversity in San Francisco filed a petition with the USA government in March 2004 requesting that these species be protected under the federal Endangered Species Act (ESA). The ESA is widely cited as the strongest and most important environmental law enacted by any nation, and places affirmative duties on the United States government to protect endangered species and recover species from the brink of extinction. The Acroporids qualify for protection under a provision in this statute that allows for protection of an entire species even though healthy populations may remain within its historic range. This precautionary approach to conservation ensures that recovery actions can be implemented before it is too late.

The following benefits would occur if these Acroporids were protected under the ESA:

- The United States government will be required to prepare a recovery plan for these species, which could include a comprehensive research strategy and a corresponding increase in funding for the study of coral diseases;
- Areas with healthy stands of coral will likely be designated as ‘critical habitat’, ensuring that these core areas are protected and enhanced while the recovery plans are being implemented; and importantly;
- The listing of these corals would require that greenhouse gas emitting industries under U.S. jurisdiction consider the well-being and recovery of these corals before being granted permits to pollute, thereby providing the only mechanism available under current U.S. law to assess the impacts of greenhouse gas emissions on sea surface temperatures, rises in sea levels, and the concomitant impacts on coral reefs.

The U.S. government responded in June 2004 to the petition from the Center for Biological Diversity stating that the listing may be warranted, and initiated an internal review of the status of Acroporids. A final determination to protect these species under the ESA is expected by March 2005 (from Brent Plater, Center for Biological Diversity, San Francisco; [bplater@biologicaldiversity.org](mailto:bplater@biologicaldiversity.org)).

## REGION-WIDE DECLINE OF CARIBBEAN CORALS

Evidence is emerging of a definite, consistent and long-term decline in the status of coral reefs of the Caribbean. These are the conclusions of a group of researchers at the University of East Anglia, England, who analysed monitoring data from 263 sites from 65 separate studies spanning 3 decades. The monitoring studies varied from a few long-term time-series to many short-term measures at single locations throughout the Caribbean. The regional pattern of decline is alarming; with coral cover decreasing from more than 50% on average in 1977 to approximately 10% in 2001, i.e. a loss of 80% in 25 years. Coral reefs normally show variations in coral cover, but this rate of change is unprecedented for this region.

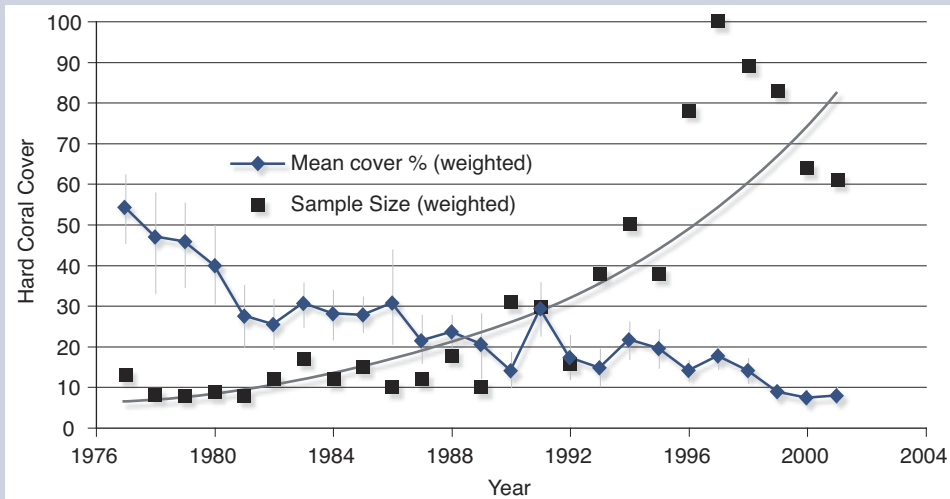
Virtually all sites showed a decline in coral cover over the study period with the loss averaging 5.5% in coral cover annually throughout the Caribbean. Such a 'meta' analysis based on uneven sized samples and markedly different monitoring methods requires close inspection. The researchers used several calculations to remove potential errors, such as controlling for the coral cover at the beginning of each study, because sites with high coral cover can show greater absolute losses than sites with lower coral cover. But these results correlate closely with reports from GCRMN Nodes about their reefs since these Status reports started in 1998.

Most of the absolute loss in coral cover occurred in the 1980s, particularly in Jamaica and northern and southern Central America. These losses resulted from 3 major impacts. White-band disease swept through the region and caused massive destruction of *Acropora* corals; the mass mortality of the sea urchin *Diadema antillarum* resulted in sudden and massive overgrowth of algae, and the first major coral bleaching events also reduced coral cover. There is evidence that the rate of loss abated in the 1990s, especially in Florida,

The **Reefs at Risk project in the Caribbean** in 2004 arrived at equally alarming estimates of coral reef decline (Box p 460). This included assessing coastal development, watershed-based sediment and pollution, marine-based pollution and damage, and over-fishing threats throughout the wider Caribbean and the major findings were:

- That 64% of Caribbean coral reefs are threatened by high levels of human activities, especially the Eastern and Southern Caribbean, Greater Antilles, Florida Keys, Yucatan, and the Mesoamerican Barrier Reef.
- Coastal development threatens 33% of the region's reefs. The threat is greatest in the Lesser and Greater Antilles, Bay Islands of Honduras, Florida Keys, Yucatan, and Southern Caribbean.
- Land-based sources of pollution and sediments threaten 35% of Caribbean coral reefs, most notably Jamaica, Hispaniola, Puerto Rico, the high islands of the Lesser Antilles, Belize, Costa Rica, and Panama. Pollution and damage from ships threatens 15% of coral reefs, especially around large ports and cruise tourism centres.
- Over-fishing threatens more than 60% of Caribbean coral reefs, particularly on narrow coastal shelves near human population centres.
- Diseases and rising sea surface temperatures threaten reefs across the Caribbean;

the US Virgin Islands, Puerto Rico, Jamaica and southern Central America. However, the rates of loss in coral cover have increased in the past decade in northern Central America and the leeward Netherlands Antilles; the 2 areas that were widely considered to be among the most pristine in the Caribbean. Coral losses in the 1990s were predominantly climate-related i.e. hurricanes and bleaching during strong El Niño-Southern Oscillation events. This may indicate that global climate change events have already damaged coral reefs in the Caribbean and pose real threats for the future. From: Isabelle M. Côté, email: i.cote@uea.ac.uk



There is clear evidence of losses in coral cover on Caribbean coral reefs from 1977 to 2001. These data were compiled from 263 different monitoring studies and published by Gardner et al. 2003 in *Science* (vol. 301, 958-960)

- Ineffective MPA management threatens Caribbean coral reefs with only 6% of 285 MPAs rated as effectively managed; and
- There will be large economic losses if coral reef degradation continues with a predicted loss of \$350-870 million per year by 2015 of the US\$3,100 million to \$4,600 million of current annual benefits from fisheries, dive tourism, and shoreline protection services.

**Conclusions and Recommendations:** Actions are required at local, national and international scales to: implement better management practices; make fisheries more sustainable and improve yields by protecting breeding stocks; protect reefs from direct damage; and to integrate conflicting approaches to management in the watersheds and adjacent waters around coral reefs.

Fundamental to supporting these actions is a wider involvement of the public and stakeholders in the management processes, as well as an improved understanding of the importance of coral reefs, especially the economic value of coastal ecosystems. Understanding the linkages between human activities and changes in coral reef condition is critical to implement the necessary changes in management, and strengthen political will and community support for

these changes. From: Laretta Burke (lauretta@wri.org), Jon Maidens (jmaidens@wri.org) World Resources Institute, Washington, DC 20002; details on [www.reefsatrisk.wri.org](http://www.reefsatrisk.wri.org)

The **Executive Summary from the Pew Foundation Report** presented a similar assessment of the world's coral reefs. This was a synthesis of the literature on the state of knowledge on coral reefs as a contribution to the debate over reef status and the future threats posed by climate change. The major conclusions of Pew Report are:

- 1) ***Climate and localised non-climate stresses interact, often synergistically, to affect the health and sustainability of coral reef ecosystems.*** Climate change presents one set of challenges to coral reefs, but rather than acting independently, tends to exacerbate the cumulative effects of other non-climate stresses. Thus, reef condition nearly always reflects both climate and non-climate factors.
- 2) ***Coral reef alteration, degradation, and loss will continue for the foreseeable future, especially in those areas already showing evidence of systemic stress.*** We are entering a climatic state that has not occurred for probably millions of years. Predictions of climate change, human alteration of the environment, and ecosystem response to those changes, contain large uncertainties. However, it is almost certain that continued climate change, particularly in combination with accelerating non-climate impacts, will cause further degradation of coral reef communities.
- 3) ***The effects of climate change on global coral reef ecosystems will vary from one region to another.*** Climate change may be beneficial to certain coral species in specific regions, but most of the effects of climate change are stressful rather than beneficial. Reef systems at the intersection of global climatic and local human stresses will be the most vulnerable. Remote, deep, or well-protected reef communities are more likely to provide reserves and refuges for future generations of coral reef organisms.
- 4) ***While the net effects of climate change on coral reefs will be negative, coral reef organisms and communities are not necessarily doomed to total extinction.*** The diversity of coral species, the adaptation potential of reef organisms, spatial and temporal variations in climate change, and the potential for human management and protection all provide possibilities for reef survival. Nevertheless, the number of coral reefs will continue to decrease and their community composition are likely to change significantly, and these changes will cause further ecological and economic losses.
- 5) ***Research into adaptation and recovery mechanisms, and enhanced monitoring of coral reef environments will permit us to learn from and influence the course of events rather than simply observe the decline.*** Most non-climate stresses can be mitigated and managed more readily than global climate change. A distributed international network of coral reef refuges and marine protected areas would be a significant first step toward these goals. Yet, even with such efforts, recent degradation of coral ecosystems combined with future climate change will still pose a significant challenge to the global sustainability of coral reefs. From: Buddemeier RW, JA Kleypas and R Aronson. 2004. Coral Reefs and Global Climate Change. Potential Contributions of Climate Change to Stresses on Coral Reef Ecosystems, Prepared for the Pew Center for Global Climate Change. 42 pp.

## THREATS AND STRESSES TO CORAL REEFS

This Status Report focuses on ‘The Top Ten’ threats and stresses to coral reefs around the world. They are listed in an order that does not necessarily reflect the degree of damage they cause to coral reefs. The rank of these threats will change considerably in different areas of the world; pollution is greater threat in some areas, whereas over-fishing is more destructive in other areas; while on remote reefs, the threat of global climate change will be the major threat. However, poor awareness of the problem and insufficient political will is usually a causal agent behind damage to coral reefs and a threat to their future survival.

### Global Change Threats

- **Coral bleaching** – caused by elevated sea surface temperatures due to global climate change;
- **Rising levels of CO<sub>2</sub>** – increased concentrations of CO<sub>2</sub> in seawater decrease calcification rates in coral reef organisms;
- **Diseases, Plagues and Invasives** – increases in diseases and plagues of coral predators that are increasingly linked to human disturbances in the environment.

### Direct Human Pressures

- **Over-fishing (and global market pressures)** – the harvesting of fishes and invertebrates beyond sustainable yields, including the use of damaging practices (bomb and cyanide fishing);
- **Sediments** - from poor land use, deforestation, and dredging;
- **Nutrients and Chemical pollution** – both organic and inorganic chemicals carried with sediments, in untreated sewage, waste from agriculture, animal husbandry and industry; includes complex organics and heavy metals;
- **Development of coastal areas** – modification of coral reefs for urban, industrial, transport and tourism developments, including reclamation and the mining of coral reef rock and sand beyond sustainable limits.

### The Human Dimension – Governance, Awareness and Political Will

- **Rising poverty, increasing populations, alienation from the land** – increasing human populations put increasing pressures on coral reef resources beyond sustainable limits;
- **Poor capacity for management and lack of resources** – most coral reef countries lack trained personnel for coral reef management, raising awareness, enforcement and monitoring; also a lack of adequate funding and logistic resources to implement effective conservation; and
- **Lack of Political Will, and Oceans Governance** – most problems facing coral reefs are tractable for solutions if there is political will and effective and non-corrupt governance of resources. Interventions by, and inertia in, global and regional organisations can impede national action to conserve coral reefs.

The true natural threats are not considered further as coral reefs generally have strong potential to recover from tropical cyclonic storms, fresh water inundation, geological events, like earthquakes and volcanoes, and low levels of plagues and diseases. The caveat about recovery is that additional anthropogenic stresses are not imposed on the reefs, and the level of these

### **WIDESPREAD CORAL BLEACHING IN THE CARIBBEAN: 1983-2000**

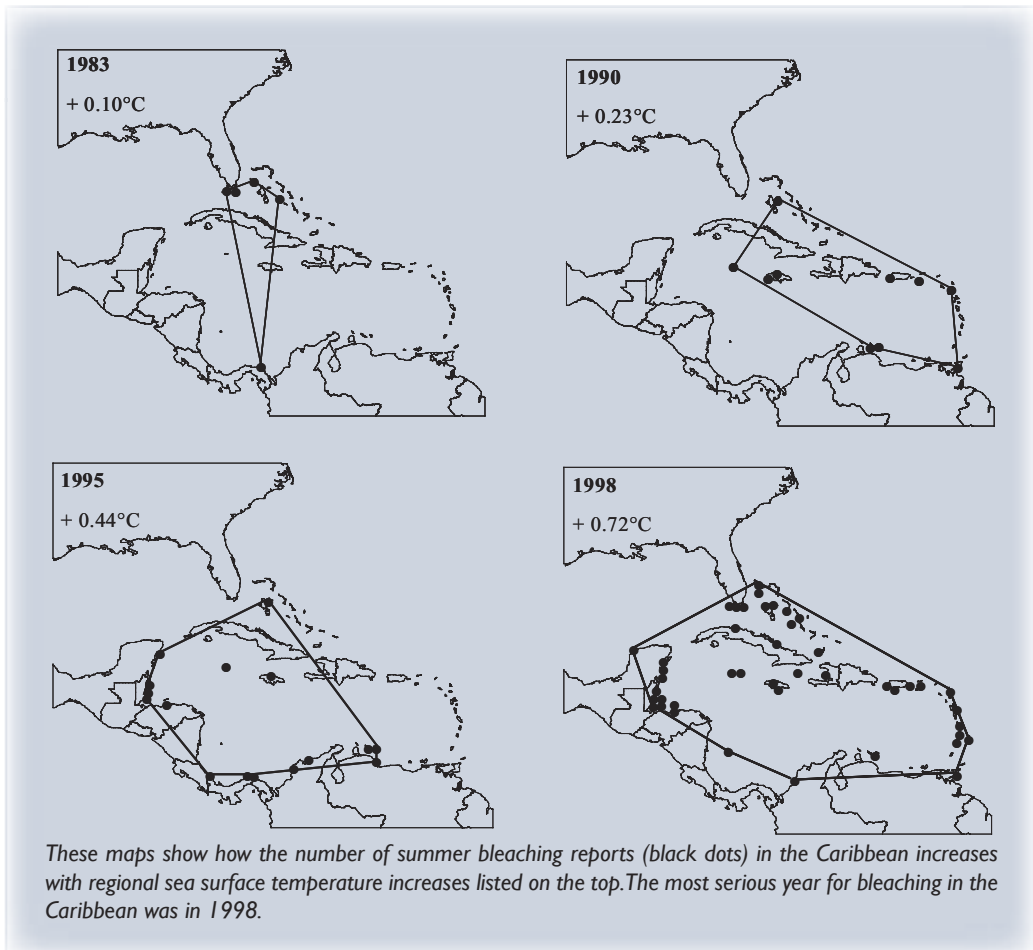
There is evidence that the timing and location of bleaching events in the wider Caribbean is increasing, although the number of sites reporting bleaching is highly variable among events. Bleaching incidence is very closely associated with variation in sea surface temperature (SST). Researchers from the University of East Anglia, England measured the geographic extent of coral bleaching by counting the number of 1° latitude / longitude cells that contained coral reefs in the Caribbean and where bleaching occurred in 1983 to 2000. They compared these with deviations in summer sea surface temperatures (SST) from the 1961-1990 average. There was close correlation between the extent of bleaching and the rise in temperatures, with more widespread bleaching occurring in hotter years. The relationship was not linear, but exponential such that for each small rise in temperature, there was a greater increase in bleaching reports e.g. a 0.05°C increase in regional SST anomaly resulted in 16% more cells showing bleaching. This does not directly transfer to specific bleaching at coral reef sites, as local factors such as wind speed or cloud cover will influence bleaching, but the potential for bleaching in a wider area is enhanced. This close relationship between geographic extent of bleaching and temperature leads to the prediction that 100% of areas with coral reefs should experience bleaching when the regional SST anomaly increases to just over +0.9°C. This is close to the +1.0°C threshold frequently reported as the critical limit for coral reefs and to the most conservative projected increases in SST for the Caribbean by the end of this century (1.0°C). From John McWilliams (j.mcwilliams@uea.ac.uk) and Isabelle Côté (i.cote@uea.ac.uk)

natural disturbances does not increase in future; this, however, is one of the predicted scenarios of global climate change. It is predicted that tropical storms could increase in frequency and severity, and the major global ocean currents may change.

Direct human damage pressures are summarised below; as they have been discussed in more detail in previous 'Status of Coral Reefs of the World' reports, and there is detailed treatment in many of the regional chapters.

The third category is more contentious: those stresses that are natural in origin, but are probably exacerbated by human activities. This category includes: stresses arising from global climate change, with coral bleaching and the potential that coral calcification will be reduced by rising concentrations of CO<sub>2</sub> in seawater; diseases of corals and other reef organisms; plagues of coral predators and other damaging animals; and invasive species that threaten to disturb the ecological balance on coral reefs by out-competing local species. These stresses are the theme for Chapter 1 Global Threats to Coral Reefs (p 67).

There is another category of 'stresses' that inadvertently result in damage to coral reefs; the human component of poor governance and a lack of political will in many coral reef countries, and the international agencies and activities that are damaging coral reefs unintentionally.



## GLOBAL CLIMATE CHANGE

The major emerging threat to coral reefs in the last decade has been coral bleaching and mortality associated with global climate change (GCC), especially major El Niño/ La Niña events. The 1998 global coral bleaching event effectively destroyed 16% of the world's coral reefs, with most damage throughout the Indian Ocean and the Western Pacific. This was apparently a 1 in a 1,000 year event in many regions based on the past history of coral reefs in these regions; very old corals around 1000 years old died from bleaching during 1998; and there is no record or memory of similar bleaching mortality in official government records or in the memories of traditional cultures. What is uncertain is whether the major climate shifts of 1998 will prove to be a 1 in a 1,000 year event in the future. The evidence is strongly against that assumption, with predictions that coral bleaching like that seen in 1998 will become a regular event in approximately 50 years time (Boxes p 22; Chapter 1 p 72), although by then most of the susceptible corals may have been lost from many coral reefs. There is a strong probability that some rare and restricted corals may become totally extinct.



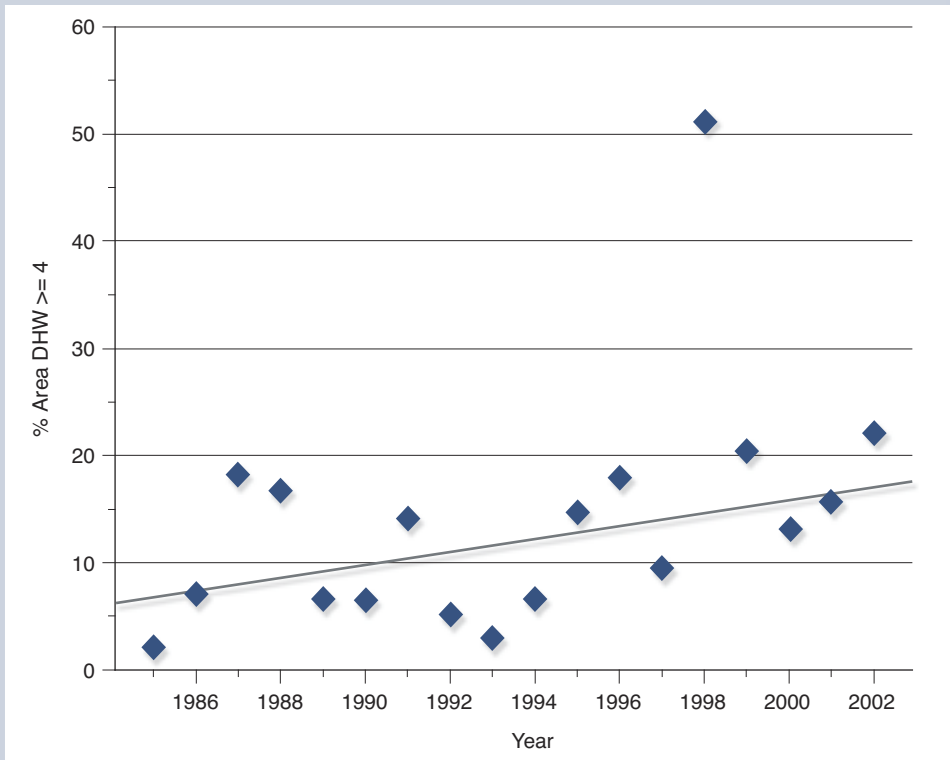
## CORAL BLEACHING – WAS 1998 A PORTENT OF THE FUTURE OR 1 IN A 1000 YEAR EVENT? SATELLITE DERIVED DATA

Coral bleaching in 1998 effectively destroyed 16% of the coral reefs of the world, with losses in the Indian Ocean of almost 50%. During that year 1000 year old corals died and some countries reported their first bleaching e.g. Palau. Many people suspected that this was a portent of a bleak future for coral reefs. But there have been no repeat bleaching events of this magnitude in the following 6 years. The NOAA Coral Reef Watch project used satellite products to assess the relationship between accumulated heat stress and mass coral bleaching from 1985. They produced a suite of analyses, which measure the intensity (the HotSpot product) and accumulated thermal stress (the Degree Heating Week product) associated with coral bleaching. When NOAA issues bleaching warnings via the Internet, the coincident in-situ observations consistently show a direct correlation between bleached corals and Degree Heating Week values of at least 4. More than 100 bleaching warnings have been issued since 2000, and on 46 occasions field reports were received. All of these reports confirmed that coral bleaching had occurred. Thus, Degree Heating Weeks provide a good indication of the level of threat for coral bleaching.

Clearly the NOAA satellite data show that 1998 was a standout year. It will be interesting to see if this remains the case when past (paleo-climate) records are used to significantly lengthen this data set. However, there is a background upward trend in the total area of the world's coral reefs that are being stressed by abnormally warm surface waters. Although this is considerably less than some current perceptions of the increase in bleaching, it is nevertheless climatologically significant. It is important to view the 1998 event in the correct perspective; it was an unusual event in the 18-year satellite record. Such a satellite record is far too short to derive accurate climate trends. However, if the upward trend of the baseline persists, events such as 1998 could become commonplace in the latter half of this century. This is consistent with the predicted climate trends as reported by the IPCC. From: William Skirving, Alan Strong, Scott Heron, Gang Liu and Felipe Arzayus, National Oceanographic and Atmospheric Administration, USA; w.skirving@aims.gov.au, william.skirving@noaa.gov

Many coral reefs that were severely damaged in 1998 e.g. lost 90% of more of the live coral cover, are now showing remarkably rapid recovery, which has surprised many of observers who found few living corals in the vicinity to repopulate the reefs with new coral larvae. There are reports from GCRMN coordinators in the Arabian/Persian Gulf, Eastern Africa, the Seychelles, Maldives, Palau, Japan and the Great Barrier Reef of rapid recovery from virtually 0-5% coral cover, to 20–30% now. However, this is counterbalanced by poor recovery in areas nearby e.g. Persian/Arabian Gulf and Eastern Africa, as well as the Chagos Archipelago, Sri Lanka, parts of the Philippines, Indonesia and Japan. The recovery is occurring through new coral larvae, as well as regrowth from coral skeletons that were previously considered to be dead. Monitoring is also showing a major shift in the coral populations on these reefs, with the former dominant branching and plating corals (often *Acropora* species) being replaced by more massive and more resistant species. The reefs that are not recovering well are usually under strong pressures from





*The underlying trend of the annual percentage of global coral reef area with Degree Heating Week values greater of at least 4 shows a gradual increase, with the 1998 bleaching event being unusually severe. The significant trend line was statistically calculated without the 1998 value.*

human activities, especially over-fishing that is removing the algal grazing fishes, excesses of sediment and nutrient pollution, and the damaging practices of bomb and cyanide fishing.

Thus, it is predicted are that most of these reefs will continue to recover and eventually revert to the similar levels of coral cover of reefs pre-1998; **provided** that there are no repeats of damaging events similar to 1998. Unfortunately, the evidence from the Intergovernmental Panel on Climate Change, NOAA in USA, and other researchers does not provide any confidence, and the authoritative predictions are that coral reefs will continue to suffer from rising levels of global climate change, with increasing sea surface temperatures in the tropics leading to regular bouts of coral bleaching and mortality in summer months.

The current predictions are that the extreme events of 1998 will become more common in the next 50 years (the 1998 event will not be a 1/1000 year event in the future), probably at decadal scales in the first instance and an annual event in 50 years time (Box p 72), with many species lost from coral reefs.

There are several strategies and possible rectifying mechanisms for coral reefs to cope with GCC. The possibility of coral reefs migrating to higher latitudes towards the poles is unlikely, as there are few suitable broad continental shelves in these latitudes and corals rely on photosynthetic energy from their symbiotic zooxanthellae. They will not receive sufficient sunlight energy during the higher latitude winters. The other major mechanism is for corals to adapt or acclimate to rising temperatures, and there is encouraging early evidence, that corals may be able to swap their symbiotic algae for more temperature resistant ones and continue to grow in higher water temperatures.

The other major predicted changes from global climate change are: an increase in the frequency and intensity of tropical storms; more frequent and severe switches in global climate, such that El Niño - La Niña changes will be more regular; a rise in sea level; a potential shift in ocean currents; and an increase in the dissolved concentration of the greenhouse gas, carbon dioxide (CO<sub>2</sub>) in seawater. There are suggestions that the first effect of more frequent and severe storms has already happened, but clusters like the recent severe storms in the Caribbean are known from historical records and no clear trend has emerged so far. It is apparent that the interval between El Niño events has shortened from about 12 years to less than 7 years, but the record is too short for confirmation. It is also too early to assess whether the large ocean currents will change. Sea level rise will not threaten the coral reefs, but will have potentially disastrous consequences for low coral islands, especially the atoll countries like the Maldives, Tuvalu, Marshall Islands and Kiribati.

One threat from the increase in greenhouse emissions is becoming more likely and could have very serious implications for coral reefs in the future. If the concentrations of CO<sub>2</sub> in the seawater continue to rise, there could be serious consequences for all calcifying organisms: tropical corals; cold water corals; calcifying algae; and organisms like foraminifera that are major producers of calcium carbonate in many marine ecosystems.

The ultimate solution to all these global climate change threats to coral reefs and other ecosystems is to reduce the emissions of greenhouse gases that are driving global warming, while simultaneously putting maximal efforts into conserving those coral reefs that have resistance and resilience capacity to warmer waters (Box p 106).

## **DISEASES, PLAGUES AND INVASIVES**

The other major global threat to coral reefs is through an apparent proliferation of coral reef diseases and plagues of destructive organisms. The major worrying feature is the very strong suspicion and apparent close correlation that the increased incidence and severity of these threats is directly linked to damaging human activities, whether through pollution washing off the land, heat stress to corals, or through over-fishing of the organisms that can control plagues. Chapter 1 discusses recent increases in all these threats.

Coral diseases are now known to affect more than 150 species of Caribbean and Indo-Pacific corals; and new diseases are being added to the 29 described diseases. Diseases have caused more damage to the coral reefs of the wider Caribbean, than the Indo-Pacific region. The recent increases in marine diseases worldwide emphasises the need for more research and also points to potential linkages to other stresses on the corals as possible instigators of disease.

## CAN CORALS ADAPT TO COPE WITH GLOBAL WARMING?

Global warming may not spell imminent doom for many of the 800 coral species on coral reefs of the world. Recent research is showing that corals may be able to survive the higher temperatures by forming new symbiotic relationships with algae that can 'take the heat'. However, the critical question is whether sufficient species and individual corals can acclimatise sufficiently rapidly to cope with rising temperatures, when just 1°C above the long-term average can result in bleaching.

Large areas of reefs were totally devastated during the 1998 global bleaching event. Those that survived or recovered well in Kenya, Panama and the Arabian Gulf provided clues that some algal symbionts may have more temperature resistance. Field studies showed that corals in these areas contained more D-type algae than C-type, which are more sensitive. This is also evident in recent controlled research which shows that some corals can acclimatise to warmer temperatures by changing their dominant algal symbionts (zooxanthellae) from the heat-sensitive C-types to more heat tolerant D-types. This is evident in 3 places: in Panama by Andrew Baker of Columbia University, New York; on Guam in the west Pacific by Rob Rowan, University of Guam; and on the Great Barrier Reef by Ray Berkelmans and Madeleine van Oppen from the Australian Institute of Marine Science. The Australian researchers showed that the common Indo-Pacific coral *Acropora millepora* was able to increase its upper thermal limit by 1–1.5°C when it changed from C-type to D-type algae. They showed that by shifting living corals 800 km from cooler water to warmer water, the corals that had D-type algae or could acquire them from the seawater survived whereas those with C-type algae bleached and died.

It is not known whether the symbiont change was due to corals taking up new algal types from the environment, or the corals increased the ratio of one algal population in their tissues over the other. Furthermore the conditions needed for a coral to change its algal symbionts are unknown. The implications are that if this mechanism of acclimatization is as widespread as it appears, coral reefs may have significantly more 'breathing space' to respond to climate change than previously thought. However, it is not known whether symbiont change by itself is sufficient for coral reefs to adapt to current climate warming predictions of 1 – 3°C average increases in tropical sea temperatures by 2100, IPCC. However caution is required because coral reefs are extremely fragile and could become the first ecosystems to succumb to global climate change, which could destroy more than half of all reefs by 2030 to 2050. Even if this acclimatization mechanism can match global warming, the structure of the world's coral reefs will change dramatically with fewer species and probably lower coral cover. From Ray Berkelmans, AIMS Townsville, r.berkelmans@aims.gov.au; report in *Nature* (Vol. 430, P. 741)

It is apparent that plagues of predators, such as COTS, are increasingly reported around areas of human activities with the possibility that either the plagues are initiated or exacerbated by over-fishing; and/or increases in nutrients from the land favour the planktonic stages of the starfish. Unfortunately, definitive explanations for the outbreaks do not exist after decades of intensive research. There have been widespread, large-scale losses of coral cover and biodiversity

### EFFECTS OF SEAWATER CHEMISTRY CHANGES ON REEF CALCIFICATION

The threat of increasing atmospheric CO<sub>2</sub> on coral reef calcification poses a chronic and increasing threat to coral reefs. However, it is also a creeping and nearly invisible stress that receives much less attention than the more visible and acute coral reef problems like bleaching and diseases.

In 1992, Steve Smith and Bob Buddemeier cautioned that shifts in the carbonate system in seawater, driven by increasing concentrations of atmospheric CO<sub>2</sub>, could have significant effects on the calcification rates of corals and marine algae. There have been numerous studies since then to test this hypothesis. Global-scale studies confirm that the oceans are sequestering about a third of all human induced CO<sub>2</sub> emissions, with the predicted effects on the carbonate system (lower pH, lower carbonate ion concentration). Experiments on reef building organisms in the laboratory and in large coral mesocosms (enclosed chambers with controlled environments) over hours to years confirm that calcification rates decline significantly under higher CO<sub>2</sub> concentrations; 10% – 40% reduction under doubled CO<sub>2</sub> concentrations. This is the level that is predicted to occur within 50 years. Studies on the skeletal density of *Porites* coral cores, however, do not reflect the expected post-industrial revolution decrease in calcification, but instead reflect rising ocean temperatures. A few experimental, but inconsistent, studies have tested the combined effects of seawater chemistry and temperature on coral calcification; it is clear that coral calcification rates are determined by both geochemical and biological controls. On the other hand, several studies show that carbonate sediments dissolve faster under increased CO<sub>2</sub> concentrations, and this side of the equation is not biologically controlled.

Under any scenario, net calcium carbonate production on coral reefs is very likely to decline, and so will reef-building capacity. However, several urgent studies need to be conducted at the organism, community and reef scales: 1. measure the effects of changing controls (mainly chemistry and light) on calcification; 2. determine how decreased calcification rates affect individual organisms as well as entire communities; and 3. prepare better reef calcium carbonate budgets. From: Joan Kleypas, National Center for Atmospheric Research, Boulder, Colorado USA, kleypas@ucar.edu

on many reefs and these plagues can be added as another large-scale threat to the integrity of coral reefs. The highest densities of COTS in recent years have been in Tanzania, Kenya and on the GBR.

The potential threats from invasive species have largely been ignored until recently. While there is the likelihood that such invasives could disrupt the ecological balance of coral reefs, there is little evidence of significant deleterious effects on ecosystem processes or biodiversity. The most serious incidence was the suspected introduction through the Panama Canal of a disease that killed the sea urchin, *Diadema antillarum*, in the Caribbean in the early 1980s. There is now evidence of invasive species causing damage in Hawaii and parts of the Caribbean. The most likely causes of invasive introductions are through ballast-water or the hulls of cargo ships, or through the release of aquarium specimens in the wrong habitat.

## DIRECT HUMAN PRESSURES ON CORAL REEFS

These pressures continue to rise in almost all coral reef areas of the world, as human populations grow and increase their demand for more resources. Human activities on land result in more pollution of reefs, and over-fishing is disrupting the ecological balance. These are the stresses that are most amenable to intervention by resource managers and governments, acting in concert with local user communities. It is reported that those coral reefs remote from land influences or well managed to reduce human pressures, now have the greatest recovery potential and resilience to other pressures like global climate change bleaching and disease.

**Over-fishing:** As human populations increase and regional economies grow, there is a parallel increase in the demand for seafood. Most coral reefs within range of small fishing boats, including motor powered aluminium boats, are now over-fished with the key target species being those that are closely associated with coral reefs; the groupers, snappers and large wrasses. As catches for these decrease, fishers target all fish species using more efficient methods of traps, fine mesh nets and spears; the final resort is to use bombs and cyanide to catch the few remaining fish. This fishing down the food chain from the predators, to omnivores, to herbivores, and eventually to planktivores, has multiple effects on a coral reef. The removal of fish has been likened to removing the immune system; the net effect is that coral reefs without fish are far more susceptible to overgrowth by macro-algae, plagues of coral predators, and probably increases in disease. In addition, fishing results in direct physical damage to the coral framework, thereby further exacerbating the effects of over-fishing. Damage results from anchors, nets and traps and especially the use of explosives to stun fish hiding in the corals.

There are many reefs in Eastern Africa, South and Southeast Asia and the Caribbean where it is rare to see a fish over 10 cm long. As these areas become depleted, more fishers target remote reefs and industriously remove most suitable fishes. This mobile trade in Asia is driven by an almost insatiable market demand for live-food fish from Asian restaurants. Sharks are now particularly rare on many reefs; just to make shark fin soup. These two trades are multi million dollar industries.

One of the most effective measures to protect biodiversity, including fishes, is the establishment and enforcement of no-take MPAs. However, many national and international fisheries management authorities contend that improvement in fish abundance in areas near MPAs has to be demonstrated before more MPAs are implemented. This suggests that no-take MPAs are experiments in managing fish stocks and must be scientifically validated. The inverse is the reality. No-take MPAs on coral reefs do conserve biodiversity and retain natural ecosystems, and constitute the ‘control’ in the ‘experiment’, which is to determine whether fishing or selectively removing one component (fish) from an ecosystem is detrimental. Thus, the hypothesis should be: ‘does fishing remove fish from an ecosystem and does over-fishing affect the biodiversity and ecological balances on a coral reef’; the no-take zone then become the control for this experiment as an un-fished ecosystem.

Unless fishing pressures can be reduced through providing alternative livelihoods and employment for fishers, through sustainable aquaculture and through establishing more no-take MPAs, it is predicted that there will be more collapses in fisheries stocks. The following two boxes present different views on the possibility of managing coral reef fisheries in developing countries. One view (Daniel Pauly and colleagues) is pessimistic and based on many observations of fisheries in

the developing world, especially Southeast Asia. The other view from the International Society for Reef Studies is more sober, but does not disagree and is still pessimistic.

**Destructive fishing:** Over-fishing is often accompanied by damaging practices to compensate for the depletion in fish stocks and to feed the demand for high priced species for Asian restaurants and the aquarium trade. Bomb fishing is largely restricted to Southeast and East Asia, although it has occurred in Eastern Africa and parts of the Pacific. Bombs are used when fish stocks drop making hook and line, and net and trap fishing un-profitable. Cyanide was first used to catch small aquarium fish, but it has expanded to capture live fish for the restaurant trade. The fish

### SUSTAINABLE CORAL REEF FISHERIES: POSSIBLE OR AN OXYMORON?

Almost 75% of the world's coral reefs occur in developing countries where human populations are increasing rapidly. Although coral reefs occupy only 0.1% of the ocean surface, their fisheries resources provide millions of people with food and livelihood. However, coral reefs are under increasing human pressures that threaten their ability to provide food and other ecosystem services. These pressures include over-fishing and indirect threats such as deforestation and land management polluting reefs with sediments and nutrients.

It has been assumed that the high primary productivity of coral reefs implies parallel high fisheries yields, however, this long-held notion that coral reef fishes are 'fast turnover' species, capable of high productivity, is increasingly challenged. Yield estimates for coral reefs vary widely, although the total global annual yield is most likely 1.4–4.2 million tones, which represents only 2–5% of global fisheries catches. Reefs, however, provide important and probably irreplaceable sources of animal protein for fisher families. It is now clear that maintaining the biodiversity of healthy reefs is the key to maintaining sustainable reef fisheries. Yet coral reefs throughout the world are being degraded rapidly, especially in developing countries, and there are widespread concerns about over-exploitation of reef fisheries. As more and more fishers, both traditional and non-traditional, attempt to take fish from reefs, there is an increasing use of destructive fishing methods such as bombs and poisons; this process is known as 'malthusian overfishing'. Another major problem is the growing international trade for live reef fish for the Chinese restaurant trade. These fish are often caught by mobile fleets using cyanide, and targeting species that are territorial on reefs. This leads to serial depletion of large coral reef fishes, notably the humphead wrasse (Labridae), groupers (Serranidae) and snappers (Lutjanidae), and to reefs devastated by the cyanide poisoning. Such fisheries destroy fish habitats, therefore are by definition, there are inherently unsustainable. Coral reefs are under dual attack with global climate change threatening further damage, and current levels of subsistence and commercial reef fishing are increasing as more fishers enter the fisheries. Thus, there is little chance of 'sustainable reef fisheries' when the pressures keep mounting exponentially and the likely future scenario is total depletion of many stocks with localised extinctions of some species. From: Daniel Pauly, Villy Christensen, Sylvie Guénette, Tony Pitcher, U. Rashid Sumaila, Carl Walters, Bob Watson & Dirk Zeller. Published in 'Nature' Vol. 418, 8 August 2002



## SUSTAINABLE FISHERIES MANAGEMENT IN CORAL REEF ECOSYSTEMS

The sustainable management of coral reef fisheries is a more challenging task than managing other fisheries because: there is a high diversity of target and non-target fish and invertebrates; the numbers of people involved in fishing is proportionally much higher; the variety of fishing methods used is particularly high; many of these fishers live in extreme poverty and resort to fishing when other resources or work are not available; reef are highly variable in fish stocks and harvestable productivity; and reefs are often particularly remote making surveillance and enforcement nearly impossible.

There are several clear differences in coral reef fisheries compared to others. Coral reef productivity rivals intensive agriculture, like sugar cane farming, but the fisheries yield is less than 1% of this production. Coral reefs maintain a balance between production and consumption, with only small excess available for 'export' off the reef. Other ecosystems like up-welling areas produce 50 times more fish than coral reefs. However, reefs do support important fisheries for tropical people with yields ranging from 0.5 to 50 tons per kilometre per year. The catch per person on remote reefs in the Indian Ocean is around 60 kg per day, whereas heavily fished reefs produce less than 3 kg per day per person. Fisheries management methods introduced and enforced by traditional or indigenous management and corroborated by national and international institutions and policies are more likely to succeed. These include strict species-specific management of stocks; application of quotas or legal sizes of fish; reductions in human fishing effort; restrictions on fishing gear, size of fish taken, times and space; and prohibition of methods that are destructive to habitats and small fish. Nevertheless, even fairly low levels of fishing with non-destructive gear will reduce top-level carnivores, and closures in time and space are needed to maintain their populations. Closed areas may range from reefs that are too dangerous to fish, to highly managed tourist or enforced MPAs. The global market for coral reef fisheries products is driving the unsustainable harvesting of some species and needs to be discouraged, regulated, or stopped. National and international laws and management institutions need to support local efforts, cultures and institutions to maintain a local balance between resource production and consumption and discourage export and global marketing of the resources.

Recommendations: coral reefs should be managed for their high biodiversity, and not as sources of food or luxury products; the trade in coral reef resources should be restricted to species that can be harvested sustainably; temporary local restrictions should be used for key target species, especially during reproductive periods; some species such as triggerfish and parrotfish are important in coral reef ecology and should not be harvested; local, national and international leaders should ban gear that is destructive to coral reefs; gear, such as fine mesh traps, that catch small fishes should be discouraged; co-management of resources by local communities should be encouraged to prevent collapse in fish stocks and improve enforcement; and management needs to be adaptable to local conditions, traditional management techniques, and fishing cultures to ensure a more effective self-enforcement of regulations. The major need is to ensure that significant areas of coral reefs are provided with high protection to ensure the protection of biodiversity and fish breeding stocks. Summarised from Briefing Paper 4, International Society for Reef Studies (ISRS) [www.fit.edu/isrs/](http://www.fit.edu/isrs/)

can be resuscitated after being stunned; although there is usually permanent liver damage. The use of cyanide, however, usually results in death of corals and other reef organisms, resulting in a wasteland.

**Sediment pollution:** Most developments on land and within reef catchment increase the flow of sediment onto coral reefs. Sediments are inimical as they reduce light energy for the photosynthetic corals, increase rates of disease and bioerosion, and eventually bury the corals. The rate of sediment release into the oceans is increasing, as more coastal lands are developed to accommodate rising urban populations and increases in agriculture. One of the major increases is through tropical deforestation, often by clear felling for tropical timbers and agriculture, such as oil palm plantations in Southeast Asia and the Western Pacific. These impacts are clearly being felt in Indonesia, Papua New Guinea and the Solomon Islands. In parts of Micronesia, steep upland forest areas are being cleared to grow 'sakau', a type of mildly intoxicating 'kava'.

**Nutrient Pollution:** This has been covered extensively in previous Status reports. However, it is suffice to say that reefs are damaged by excess nutrients that: favour the growth of macro-algae when the populations of grazing fishes and sea urchins are reduced; increase phytoplankton growth in seawater, thereby reducing light energy penetration to the light-dependent corals; favour the growth of other competitors of corals, especially those that bore into coral skeletons, such as sponges, molluscs, worms and burrowing algae; and probably make corals more susceptible to disease. All reefs near human populations or adjacent to large land masses suffer degradation from nutrient pollution.

**Development on coral reefs:** As populations increase on the coast, so do the pressures to alienate land from the sea for development. There are currently large plans to 'reclaim' coral reef areas in the Persian/Arabian Gulf, especially in United Arab Emirates, in the Red Sea along the coast of Saudi Arabia, in Singapore and recently in Peninsular Malaysia and southern Japan to build airports on coral reefs to attract tourists. Virtually all coastal developments result in sediment damage to fragile corals, however, some activities have long lasting effects. The building of marinas, groynes and causeways around coral reefs disrupt currents and often cause major displacements of sediment. Causeways on some Pacific islands have resulted in considerable coral death and reduced fisheries in coral lagoons.

Many countries have prohibited the mining of coral rock and sand from sensitive areas on and around coral reefs. This was in recognition of the damage that excessive mining had on reefs and their potential to provide other goods and services, such as fish productivity, shoreline protection and attracting tourists. Mining is still practiced in some countries where there are limited sources of sand and limestone on land, or where governments do not enforce the regulations, such as in South Asia.

## OCEANS GOVERNANCE AND POLITICAL WILL

A threat reported by many regions was the undercurrent of the human dimensions of inadequate governance, a lack of awareness of the problems facing coral reefs and insufficient political will to combat the obvious and hidden threats coral reefs. Governments have often declared MPAs and passed well-drafted legislation to protect coral reefs, but there is little follow-up action to manage MPAs and enforce the regulations. There are many explanations for the poor



governance and low political will to conserve coral reefs. Most tropical countries have rapidly increasing coastal populations, consequent rising levels of poverty, which put increasing pressures on coral reefs to provide food and other resources; usually beyond sustainable limits. These pressures have caused, and will cause, collapses of coral reefs and phase shifts towards algal dominated reefs at the expense of corals.

Many developing country governments seek to solve the immediate needs and problems of providing health, housing, education and nutrition, and postpone action on the longer-term, and potentially more difficult problems, of ensuring that environmental goods and services are conserved for the future. The resources needed to build management capacity by training young graduates in environmental management, and providing the funding and logistic resources to implement effective conservation are lower on the priority list; environmental management can be solved after the immediate problems are removed.

A contributing factor has the replacement of traditional resource management, with 'Western' or 'modern' methods of governance. The traditional management approach was consensus based or 'integrated coastal management', often with the whole community involved in prior discussions before decisions were made that could affect the natural resources of the community; the resources were the property of the community. The Western model introduced a cash economy, the concept of free access to all marine areas, and a sectoral government approach, with a fisheries department to maximise fish harvest, a forestry department to maximise returns from trees, and the environment department tasked with conserving both resources and the whole ecosystem, but provided with few resources and staff. Moreover, many of these governments consider that they must combat global climate change, because they will experience the first consequences, but are not responsible for the problem.

The critical issues to improve coral reef (and oceans) governance is: a firm basis of local, national and international environmental policies and regulations to ensure the sustainable use of coral reef resources; effective mechanisms to implement those policies and regulations, including reviews on the effectiveness of the implements and the mechanisms in conserving resources; and improved capacity for coral reef management in these countries and the provision of resources for actions to avert the potential collapse in coral reef resources. An example is the WSSD call for networks of larger and effectively managed MPAs; developing countries will need assistance to achieve these.

## **INTERNATIONAL ACTION OR INACTION**

Many international agencies, including organisations of the United Nations, national donors and NGOs, assist countries with activities to conserve coral reef biodiversity, reduce threats, introduce integrated coastal management, and assist communities develop alternative and sustainable livelihoods. These efforts are achieving considerable successes. However, many international agencies are inadvertently exacerbating the problem of poor capacity in many developing countries.

Of the 100 coral reef countries and states reported in this book, 21 have populations under 100,000, and a further 23 have populations under 1 million. These countries must establish the full range of government, and be represented on UN bodies and Multilateral Environmental Agreements (MEAs). For example, the major MEAs concerned with coral reefs; the Convention

on Biological Diversity, Framework Convention on Climate Change, the World Heritage Convention, as well as the CITES, Ramsar and Migratory Species conventions which focus on protecting biodiversity, all seek to assist countries with natural resource conservation and environmental management. However, this assistance is often dependent on the production of regular reports to convention secretariats and the need attend annual or biannual meetings in distant, expensive lands. Unfortunately, these reporting and meeting requirements and some training programs, divert the few trained environmental staff from direct activities aimed at conserving coral reef resources. Thus, there is need to rationalise the meeting and reporting requirements of the MEAs and other UN agencies to ensure that more time is spent on activities directly related to resource conservation.

The Kyoto protocol to reduce the flow of greenhouse gases into the atmosphere and slow the accelerating rate of global climate change was drafted in Japan in 1997. This protocol, which is minimalist in its ambitions to slow climate change, has only come into force as a UN ratified convention in late 2004, with 84 parties signing and 124 either ratifying or acceding to the convention; some major greenhouse gas emitting countries are not included. Thus, 7 years have potentially been lost in reducing the threats to the world's ecosystems, including coral reefs. These delays result in cynicism amongst the smaller coral reef countries that are likely to be adversely affected by climate change, but are not major emitters of greenhouse gases.

## **PARADIGM SHIFTS - NEW CORAL REEF INITIATIVES**

### **Management of Coral Reefs**

There has been increasing awareness over the past 5 years that the 'standard' methods used to manage and conserve coral reefs and their resources were not fully effective. While there have been conservation successes in some areas, the surrounding areas continue to degrade due over-fishing and pollution. The resources in these areas are depleted, and some coral reefs have collapsed. This prompted a paradigm shift in approaches, and a shift from small-scale management activities to larger, collaborative projects. A major catalyst was the massive climate change swings of 1997-98, when a major El Niño event was followed suddenly by an equally strong La Niña event. The GCRMN Status of Coral Reefs of the World: 2000 report estimated that 16% of the world's coral reefs were effectively destroyed, and reefs that had 50% or more of coral cover were reduced to 1% to 5% live coral.

The major Paradigm shifts have been: a) increasing the area of coral reef under highly protected status; b) international cooperation to pool resources and develop larger MPAs in networks; c) a strengthened International Coral Reef Initiative and operational units; and d) a concerted effort to combine research capacity and talents to tackle the questions needed by resource managers.

a) The major conservation success of the past 5 years has been the declaration of 33% of the Great Barrier Reef and associated ecosystems as highly protected status or no-take zones. The process combined strong scientific assessment with detailed community consultation to set a global benchmark (Chapter 11). The USA has declared a large area of the Northwestern Hawaiian Islands (Chapter 15) and is increasing the area of protection in southern Florida (Chapter 16). A note of caution is needed; it is futile to declare large no-take zones without public consultation, acceptance and involvement and supported by effective legislation and enforcement. The world has enough 'paper parks'.

b) The WSSD in Johannesburg, 2002 recognised that single isolated MPAs run by under-resourced governments, communities or NGOs were unlikely to be effective to conserve sufficient coral reef area in the face of growing threats of global change. This was emphasised in 1998 when well-managed, small MPAs succumbed to coral bleaching mortality and the nearby healthy populations of reproductive corals were not protected. WSSD made a recommendation that larger networks of MPAs be established, preferably through combining of resources of all sectors.

Three major NGOs (Conservation International, The Nature Conservancy and WWF) have combined their expertise to develop training packages in the implementation of MPAs and in developing networks of MPAs in the areas of highest biodiversity in Southeast Asia and the Western Pacific. These are detailed in Chapter 2 (Box p 94 and p 95). Similar partnerships have been developed between NGOs (WWF, TNC and the WorldFish Center) and government agencies in Australia (Great Barrier Reef Marine Park Authority) and USA (National Oceanic and Atmospheric Administration) to develop packages to assist coral reef managers cope with the rising rates of global change. The R2 Concept of Resistance and Resilience and the bleaching advice for managers have been produced within the last year and made freely available for managers in the field.

c). There has been increased cooperation arising through the International Coral Reef Initiative and operational units; and greater involvement of governments, UN agencies and NGOs for coral reef conservation. One example is from the GCRMN, which has produced 4 guidebooks to assist coral reef managers with improved monitoring of their resources. These were produced under the ICRI umbrella and supported by partner countries and agencies.

When coral reefs in the Indian Ocean were devastated in 1998, the Government of Sweden, neighbouring governments and the World Bank developed the CORDIO program – Coral Reef Degradation in the Indian Ocean. The goals were to investigate the ecological and socio-economic consequences of the massive loss of corals on the countries and communities of the wider Indian Ocean and then seek solutions to improve management of affected reefs and enhance recovery. The CORDIO program has been refunded by Sweden and they will coordinate coral reef monitoring for the GCRMN in association with the IUCN in South Asia (Box p 110).

Another ICRI partner, the government of France, has initiated a major coral reef program in the Pacific, starting in early 2005. This project seeks to develop sustainable ways of using coral reefs and providing alternative livelihoods for the peoples, with a strong basis of research and applied science. The AFD project will assist the coordination of coral reef monitoring for the GCRMN in the Southwest Pacific (Box p 112).

A major initiative at a regional scale is the PEMSEA project (GEF/UNDP/IMO Regional Program on Partnerships in Environmental Management for the Seas of East Asia). This project is working with 12 governments of Southeast and East Asia on integrated coastal management, including managing coral reefs. One theme is to train local government officials in establishing MPAs to conserve biodiversity and living coastal resources ([www.pemsea.org](http://www.pemsea.org)).

### **Marine Protected Areas (MPAs)**

It is widely recognised that one of the better methods of protecting coral reefs is through MPAs and affording them highest level of protection possible. The declaration of 33% of the Great Barrier Reef World Heritage Area with highly protected status is an example for other governments. Throughout this Status 2004 report, there are many references to MPAs and many more have been declared in the past 2 years; however many MPAs are not well managed or not managed at all. There is strong recognition amongst international agencies that developing countries need scientific, logistic and financial support to designate and manage coral reef MPAs to safeguard biodiversity of global importance.

### **Science on Coral Reefs**

New science-based initiatives that have been initiated recently to improve the chances of sound decision making to conserve coral reefs:

- a) The Targeted Research program of the World Bank and the Global Environment Facility;
- b) Large scale meta-analyses of either long time scales or large area scales of the past history of coral reefs and assessments of their status;
- c) Rapid biodiversity and status assessments of coral reefs to select the most suitable areas of conservation priority; and
- d) Development of new tools to assist managers select reefs against and guide them through the current bout of global scale.

a). The Targeted Research project is discussed in Chapter 2; it is hoped that the provision of considerable dedicated funds and the combination of many research teams around the world will provide advice for reef manager and policy makers to improve coral reef conservation.

b). This report contains several examples of large-scale analyses of coral reefs. Reports from the Caribbean indicate major long-term degradation of Caribbean coral reefs (above). Particularly alarming was from a multi-disciplinary team assembled by Jeremy Jackson of the University of California, San Diego, that showed over-exploitation of coral reef resources and associated degradation started 10,000 years ago when humans started removing easy prey. These analyses have radically changed the way we examine coral reefs and also act as an extended baseline for coral reef managers.

c). & d). New tools are being developed to assist coral reef managers select the best sites for MPA designation and implement actions to improve reef conservation in the face of global change. These management tools were developed on a basis of sound science and discussed in Chapter 2. Some of the large NGOs, WWF, The Nature Conservancy and Conservation International, have developed rapid biodiversity assessments, combined with assessments of general resource status and existing pressures and threats to select areas for protection and management. Although the names differ, these employ similar techniques and biodiversity experts to provide an expert 'snapshot' of an area; these are detailed in Chapter 2 and in Chapters 7, 9 and 12.

### **RIISING PUBLIC AWARENESS OF CORAL REEF PROBLEMS**

Most agencies have recognised that success in conserving coral reef resources can only be assured if supported by an informed and involved public. Many of the regional chapters that follow detail new initiatives aimed at raising awareness about coral reefs and associated problems. That is also a major reason for this report.

## CORAL TRIANGLE HEADS EAST TO THE SOLOMON ISLANDS!

Until recently, the greatest concentration of coral reef biodiversity (known as the 'coral triangle') was considered to be centred on Indonesia, Philippines, and Papua New Guinea (the solid line on the map). However, a recent survey of the Solomon Islands led by The Nature Conservancy, has shown that the coral triangle should be extended further east to include this archipelago (dotted line on map). Not only should the Solomon Islands be included in the triangle, but also it contains the second highest biodiversity in the region after Central Indonesia (REA Chapter 9). This was not predicted prior to the survey, and the results show that the high diversity is due to a wide range of habitats in a small area and the generally good condition of the reefs. This now raises the profile of the Solomon Islands for marine conservation in the region. Contact: Alison Green, The Nature Conservancy, [agreen@tnc.org](mailto:agreen@tnc.org); [www.nature.org/wherewework/asiapacific/solomonislands/](http://www.nature.org/wherewework/asiapacific/solomonislands/)



## RECOGNITION OF COLD WATER CORAL REEFS

It is only during the past decade that there has been extensive scientific, political and conservation interest in cold water coral reefs. These are now on the agenda for urgent conservation measures by many international agencies and senior decision makers, and were a specific recommendation for conservation at the WSSD in 2002. The Summit urged national governments and international agencies, like the Convention on Biological Diversity, to develop a network of deep water coral reef reserves within territorial EEZ areas, and operate through UN Convention on the Law of the Sea for similar protection of reefs in international

waters. Cold water coral reefs contain high biodiversity and many of the isolated seamounts contain many rare and endemic species. These reefs are particularly slow growing and easily destroyed by large trawlers, thereby destroying their role as potential major nursery grounds, as well as obliterating biodiversity. These reefs are frequently in deep water and not accessible for research and monitoring, without the use of expensive remotely operated vehicles equipped with cameras and grabs; discussed in Chapter 3.

Marine Aquarium Council (MAC) is working to ensure the trade in marine ornamentals is responsible. In conjunction with the film's release, MAC undertook an international awareness campaign on how to ensure that marine ornamentals come from responsible fisheries that support reef conservation. The 'voice of Nemo', Alexander Gould, generously created a series of public service videos on coral reef conservation for Reef Check and MAC.

## RECOMMENDATIONS FOR THE FUTURE OF CORAL REEFS

Many countries assessed the status of their coral reefs, and make predictions for their reefs in 10 years time under pessimistic or 'business as usual' and optimistic 'implement the recommendations' scenarios. The recommendations of from the regional chapters are summarised here.

### Action to Conserve Coral Reefs

The two International statements below carry the recommendations of the coral reef science and management communities for necessary action to conserve coral reefs. The recommendations in the Reefs at Risk analysis above and Box p 460 also cover the same ground. These recommendations focus on:

- reducing and, where possible, removing the direct pressures on coral reefs through integrated catchment and coastal management to minimise the inflow of polluting sediments and nutrients into reef waters;
- managing coral reef fisheries in an attempt to make them sustainable and prohibit damaging fishing practices;
- improving fisheries yields by protecting breeding stocks in no-take MPAs, protecting spawning sites, and also in selective breeding programs to satisfy the Asian restaurant market for live reef fish;
- involving local communities in the design and management of MPAs and enforcement of regulations;
- developing networks of MPAs that are larger, contain the most resistant and resilient coral and other organism populations, and are connected to ensure a free transfer of new larvae to restock the reefs and repair damage; and
- acting locally and globally to reduce the emissions of greenhouse gases that are driving global climate change inexorably towards massive destruction of coral reefs and the possible extinction of many coral reef species.

### Action to Improve Oceans Governance – or Turning the Tide

Many countries stressed that there was a gap in their capacity to implement actions to conserve their natural resources. The main issues are: local, national and international **environmental policies and regulations** as a basis for effective conservation; functional **implementation mechanisms for policies and regulations** to improve coral reef management and conservation; and the **capacity for coral reef management** and resources for direct action on the ground and with communities.



## NEMO RETURNS

The Disney/Pixar animated film *Finding Nemo* was released in May 2003 and had some dramatic and unexpected consequences for coral reefs. It was a hugely successful film, grossing \$850 million making it the 9th largest film ever. Eight million DVD and VHS copies of *Finding Nemo* were sold on the first day of release at an average price each of US\$ 20.00, resulting in US\$ 175 million in revenues on the first day.

The lead character is a charismatic, juvenile clownfish named 'Nemo' who is captured on the Great Barrier Reef by a dentist from Sydney. Nemo escapes from the dentist's aquarium into a spit basin and out to Sydney Harbour. The film contains amazingly realistic computer graphic sequences of a coral reef, with accurate coral reef biology in an easily understood and entertaining format.

The public response to the film was dramatic beyond the box office and video sales counter. The film created increased interest in aquarium keeping and sales of aquarium fish, especially clown fish like 'Nemo', surged. On the other hand, according to the media in Southern California, the film inadvertently encouraged idealistic children to 'save' aquarium fish by releasing them into sinks and toilets. The calls to plumbers from frantic parents apparently became so frequent that one plumbing company created an ad campaign called "Don't Flush Nemo!"

More importantly, the 'Nemo' craze provided an opportunity to improve the information and awareness of home aquarists and the public about coral reef fish and the reefs themselves. For example, Reef Check teams have found breeding colonies of 'invasive species' such as Indo-Pacific lionfish and batfish on the reefs of Florida and used this opportunity to raise awareness about releasing marine ornamentals into foreign environments. The Marine Aquarium Council (MAC) is working to ensure the trade in marine ornamentals is responsible. In conjunction with the film's release, MAC undertook an international awareness campaign on how to ensure that marine ornamentals come from responsible fisheries that support reef conservation. The 'voice of Nemo', Alexander Gould, generously created a series of public service videos on coral reef conservation for Reef Check and MAC.

*Finding Nemo* boosted public interest in coral reefs, raised awareness about coral reef conservation and provided incentives for the industry to address the impacts of the trade in marine aquarium organisms. The film brought coral reefs to an enormous number of family homes in an entertaining way. 'Nemo' got a powerful message out about reefs and reef conservation with a production budget of \$90 million and advertising budget of \$40 million.

**Environmental policies and regulations:** There are many international policies and regulations, with the Law of the Sea Convention, the Climate Change Convention and the Multilateral Environmental Agreements (MEAs; World Heritage, CITES, Ramsar and Migratory Species). Most governments have developed strong national legislation; thus the urgent issue is not to develop more of these, but ensure that they are implemented. There is a need is to:

- ensure that local user communities and the private sector are aware of these environmental policies and regulations and have access to their provisions to manage environments on the ground;
- ensure that international community provides incentives for communities and governments to manage their resources sustainably. Market based incentives are an effective mechanism to assist communities;
- increase recognition in national and international policy development that sustainable development and poverty reduction in many countries is not achievable without integrated watershed and marine ecosystem management;
- recognise the role that effective management of coral reef resources can play in sustainable development and poverty alleviation.

**Implementation mechanisms for policies and regulations:** This is where most effort is required; the need to develop effective mechanisms to convert the legal instruments into effective implementation in the natural environment, and to:

- develop integrated oceans, integrated natural resource and integrated catchment management groups that include all stakeholders, especially local communities and the private sector, supported by governments, that can make decisions across all sectors of government;
- devolve sufficient authority to communities to develop and run their own no-take MPAs and implement enforcement; all well supported by state and national governments;
- develop joint enforcement mechanisms with government and communities acting in concert to enforce environmental laws aimed at conserving resources;
- strengthen jurisdiction and the imposition of penalties under existing laws to demonstrate to communities that their actions are supported and that infringements are treated seriously in the courts;
- reduce the reporting and meeting requirements of UN agencies and MEAs and make them more relevant to small countries, possibly through developing regional meetings that combine several international marine environmental instruments to focus more attention on practical issues;
- assist small countries with cooperation to access international conventions and instruments as blocks and reduce their meeting and reporting requirements by forming smaller groups of states with similar cultures, problems and resources;
- review the effectiveness of implementation of international conventions and instruments to ensure that they are assisting in conserving the marine resources;
- undertake an objective appraisal of the performance of current international and regional environmental agencies to ensure that their current activities meet the stated objective of conserving environmental resources.



**Capacity for coral reef management:** Most coral reef countries lack trained personnel for coral reef management, awareness raising, enforcement and monitoring. Moreover they lack the necessary resources to implement effective management. Thus there is a need to;

- assist in the training of environmental resource managers and ensuring that they are provided with in-country employment;
- assist countries in the development of alternative livelihoods to combat poverty and reduce the need to over-exploit coral reef resources;
- assist developing countries design, implement and manage networks of MPAs to conserve their resources;
- consolidate the training provided by UN agencies and MEAs to ensure that they are targeted on resources, issues and problems relevant to conserving national resources;
- provide adequate and long-term financial and logistic resources for developing countries to undertake environmental planning for the longer-term, rather than the 3 to 5 year funding cycle of projects;
- assist in the recognition of appropriate traditional knowledge and methods of environmental management and help governments harmonise these with state and national laws;
- develop the ‘capacity to build capacity’ and use train-the-trainers and peer-to-peer exchanges as low cost mechanisms to ensure that capacity building is as a self sustaining mechanism.

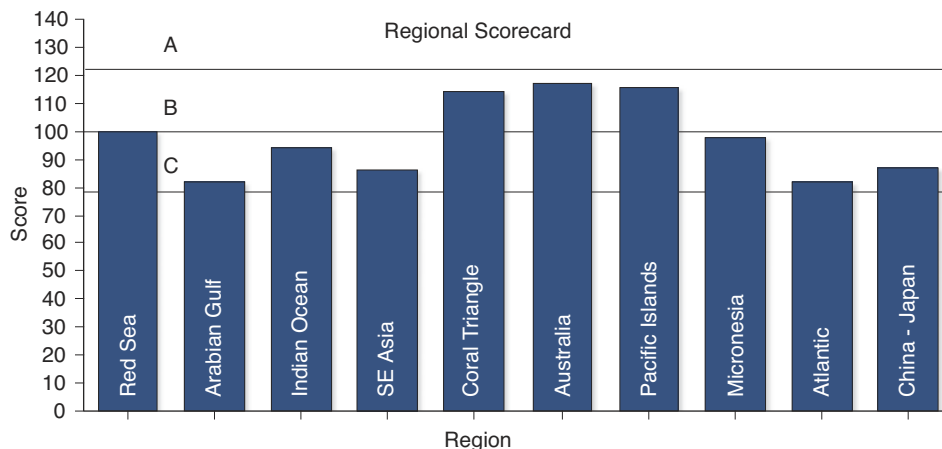
In addition, two action declarations are listed at the end of this Executive Summary. **The Okinawa Declaration** was prepared for the 10<sup>th</sup> International Coral Reef Symposium in Okinawa, Japan 28 June to 02 July, 2004 and endorsed by approximately 1,500 of the world’s leading coral reef scientists, as well as managers and decision makers. This Symposium was endorsed by the International Society for Reef Studies which has 1000 members, predominantly coral reef scientists.

The more detailed **ITMEMS Agenda** was drafted at the 2<sup>nd</sup> International Tropical Marine Ecosystems Management Symposium in Manila, Philippines March 2003 and endorsed by the 200 delegates from 36 countries. The summary at the back of this chapter is condensed from the larger statement that is reproduced in full at the end of the book in Chapter 23. This action agenda the third that has been developed by the International Coral Reef Initiative, the first in 1996 in the Philippines and the second in 1998 in Townsville Australia. These are available on [www.ICRIforum.org](http://www.ICRIforum.org)

### **REEF CHECK SUMMARY OF THE GLOBAL STATUS OF CORAL REEFS: 2003**

Reef Check, a GCRMN partner, has expanded its volunteer monitoring programs since 2002 into 70 of the 101 coral reef countries. The teams surveyed more than 750 coral reefs in 2003, and these results show that the living coral cover lost during the 1997/8 bleaching event has been largely replaced, on average, by new growth, although often in different areas. However, the number of key human impact indicators, such as food fish, continues to decline. For example, the number of sites with **zero** counts of Nassau grouper in the Caribbean and humphead wrasse in the Indo-Pacific have increased from 90 to 95% from 1997 to 2003.

The regional scorecard based on a combination of the 18 categories in the Reef Check Human Impact Index, demonstrate that the least damaged reefs in 2003 were in Australia and the Pacific Islands. This new indicator index is now available on the new WRAS interactive database, a joint product of ReefBase, University of Southern California, University of Rhode Island Coastal Resources Center and Reef Check (Box p 107). Reef Check has also been targeting major corporations to use skills for coral reef conservation issues (Box p 113). From: Reef Check, [www.ReefCheck.org](http://www.ReefCheck.org).



*This graph shows a sum of the 18 indicator grades (A = 4, B = 3, etc) in each region from Reef Check surveys in 2002 – 2003; a perfect score would be 144.*

### STATUS OF CORAL REEFS OF THE WORLD BY REGIONS

**The Red Sea and Gulf of Aden (Chapter 4):** The Red Sea reefs continue to be in relatively good health, because they are removed from direct anthropogenic threats. There is virtually no runoff from the land, fishing is at a relatively low level, although key target species like sharks are being removed, and tourism is largely concentrated in a few areas. Shipping, over-development of tourism, coral bleaching and the crown-of-thorns starfish loom as the major problems. The political awareness and will for conservation is not widespread, and monitoring and management capacity remain weak. Damage from coral bleaching in 1998 has been largely reversed in many areas.

**Arabian/Persian Gulf Region (ROPME Sea Area; Chapter 5):** The reefs off the Arabian Peninsula have shown little recovery after they were mostly destroyed during severe coral bleaching events in 1996 and 1998. The only recovery is from reefs that were less affected in deeper water; but there will be a shift in the coral species on the growing reefs to lower profile, slow growing and more resistant species. Prior oil exploitation and shipping activities, including major oil spills, had caused minimal previous damage. Near-shore reefs on the Iranian coast have also been affected by bleaching, but at a much lower level, whereas some of the offshore reefs in deeper water retain healthy corals. Awareness is increasing in this region, however there are some major development projects that are destroying coral reefs. A monitoring network was formed in late 2003 with Iran as the host country.

**East Africa (Chapter 6):** There has been significant, but very patchy, recovery of reefs devastated in 1998, with better recovery on reefs that are well managed. Coral regrowth is estimated at about 30-50%. The growing coastal population of 22 million poses the largest threat to the reefs, with land based activities and over-fishing increasing. There have been significant improvements in the management of coral reef MPAs in the last 2-4 years, due to national and regional initiatives, and greater commitments to increase the area of MPAs and improve fisheries management. Regional and international NGOs are assisting communities develop their own co-management places for MPAs, often based around tourist destinations. Ecological and socio-economic monitoring and research on coral reefs is expanding in the region due to local and international efforts.

**South West Indian Ocean Islands (Chapter 7):** There has been some recovery of coral reefs, which had been reduced to less than 5% coral cover in 1998. However, recent bleaching damage to the new coral recruits is slowing recovery. Alongside these, there are some exceptional sites that were highly resilient to the bleaching damage; but human stresses and natural disturbances pose a constant threat to these reefs. Coral reefs on the Southern Islands suffered less damage in 1998, but natural disturbances have caused some coral mortality. There has been a marked increase in awareness of the need for coral reef management and conservation, and all countries have active monitoring programs to assist in environmental decision-making. There are more monitoring sites, including remote reefs like Tromelin, Juan da Nova, Europa (France) and Cosmoledo, Assumption and Aldabra (Seychelles). The Global Environment Facility has just announced a continuation of funding for monitoring activities, which continues to expand and provide information for governments.

**South Asia (Chapter 8):** While there has been encouraging coral reef recovery in the Maldives, Chagos, Sri Lanka and Lakshadweep (India) after the massive coral bleaching mortalities in 1998, there has not been a parallel rise in awareness about the importance of coral reefs and the need for effective conservation. The possible exception is India, where there have been major advances in coral reef science with the publication of several major coral guidebooks and the formation of senior government committees and some stakeholder groups. Monitoring in the Maldives has assumed a lower priority, although there is high economic dependence on coral reef resources; insufficient national funds are allocated for monitoring or management, with the tourism sector filling the gaps. Management capacity continues to be weak in most countries with the drive for development taking priority over environmental conservation. There are, however, some excellent examples of effective management and successes in reef protection through community control. Many of the MPAs in the Maldives are managed by tourist resorts to protect their resources. Poverty continues to drive over-exploitation of fishes, invertebrates and coral rock.

**Southeast Asia (Chapter 9):** There has been a continual decline in reef condition; but there are some positive signs in some countries e.g. Indonesia and possibly Myanmar. The continued reef decline in the Philippines, Vietnam, Thailand and Singapore is a major concern. The threats to reefs remain high and dominated by human pressures; over-fishing and damaging fishing is extensive, pollution from the land affects many reefs, sediments continue to damage reefs due to coastal development, dredging and deforestation, and reclamation of coral reef areas continues for industries, airports and marinas. However, there are more active management initiatives throughout the region, and monitoring programs have improved and expanded, after a decade

of little progress. Some countries lack the expertise and resources for monitoring and there is a critical lack of effective coordination. Several major projects are starting to address the issues with assistance from UN and NGO agencies; but there is a major need for regional coordination and cooperation, and a sharing of resources for coral reef monitoring and management.

**East Asia (Chapter 10):** Pressures from human activities are the major threats to coral reefs in East and North Asia. These have been exacerbated by coral bleaching and some severe, recent typhoons. Sediment runoff is a major problem in many areas and the rate of development is threatening reefs. Fishing pressures remain at extreme levels in most areas. The coral reefs continue to decline in areas of high human activity; whereas remote reefs are recovering from the bleaching losses of 1998. All countries are developing coral conservation and management programs, and it is anticipated that these programs could be effective in conserving coral reefs in the future, provided that there are no repeat bleaching episodes like those of 1998 and that growing populations do not increase pressures on coral reefs. Mariculture is supplementing stocks of coral reef fishes and invertebrates, but also resulting in local pollution. Coral bleaching has occurred since then but most corals recovered.

**Australia and Papua New Guinea (Chapter 11):** The coral reefs remain in relatively good condition, despite some recent setbacks. However, the level of resource monitoring and management is markedly different in both countries. PNG has few trained personnel, minimal resources or low political will for coral reef conservation; fortunately the human pressures on the reefs are relatively low (but increasing). Australia has set an example for the world in coral reef conservation by declaring 33% of the whole Great Barrier Reef area as a highly protected zone; similar efforts are underway in other parts of Australia. These activities are supported by good central planning, legislation, enforcement, and research and monitoring. The only potentially effective model for conservation in PNG is a decentralised, community-based system for reef resource management driven largely by NGOs. The reefs of the GBR show highly dynamic patterns of short periods of decline from disturbances, followed by longer periods of recovery. There is an apparent, longer term trend of gradual decline, especially on inshore reefs affected by coastal pollution. The other major threats are coral bleaching and crown-of-thorns starfish outbreaks. There was a major bleaching event in 2002 and an outbreak of coral disease, but the mortality caused localised declines in coral cover, and many of the areas are recovering.

**Southwest Pacific (Chapter 12):** The coral reefs in the Southwest Pacific are generally in good condition, although there was extensive coral bleaching during 2000-2002. Some coral reefs have shown full recovery of live coral cover, whereas others have not recovered. The greatest threats to reefs continue to be human activities and cyclones, with reefs of New Caledonia, Samoa, Solomon Islands and Vanuatu having been damaged by cyclones since 2002. Other threats are crown-of-thorns starfish plagues and disease. The human pressures of over-exploitation and pollution are concentrated around the cities and towns, and in lagoons. There is increased participation of governments, NGOs, scientists, volunteers and local communities in coral reef protection and conservation, with more plans for sustainable management of resources. There has been an increase in monitoring training and field surveys, however there is a lack of sustainable funding and support, and political will for the necessary conservation measures is weak.

**Southeast Pacific (Chapter 13):** The coral reefs of Polynesia Mana are predominantly healthy and under a low risk of damage in the immediate future. The reefs are probably the least degraded in the world as they are remote from most human damage, however predicted global climate change threats of more cyclones and coral bleaching are the major concern. Monitoring is developing, with some countries having ongoing programs, whereas others are starting. Local populations are reviving cultures and traditions for sustainable reef management. Political awareness and will for coral reef conservation is increasing, but more effort is needed to combat the threats of increased sedimentation, over-fishing, dredging and nutrient pollution. If governments fail to implement coral reef resource management and do not remedy the causes of human stresses to the reefs around the heavily populated islands, these reefs will continue to decline, especially with lower fish stocks. The majority of the reefs are remote and should remain healthy.

**Micronesia (Chapter 14):** This region has some of the most diverse and pristine reefs in the world, but the cumulative impacts of sedimentation, increasing population demands, commercial fisheries, coastal pollution, ship groundings, and recreational activities are apparent on many reefs. Human population growth is the main factor behind increasing disturbance. Isolated reefs are in good condition, but many near population centres, and around the high islands, are declining with decreases in coral cover, low fish abundance, sediment damage, and poor resilience to disease and bleaching. Coral reef monitoring and management continues to improve, with significant regulations banning scuba fishing, 'live rock' harvesting, and hunting of turtles and marine mammals. Monitoring activities have been boosted by increased support for the Palau International Coral Reef Center and more awareness in Micronesian countries. Governments and NGOs are developing more MPAs, and combining these into networks to conserve biodiversity.

**Northeast (American) Pacific (Chapter 15):** The Hawaiian Archipelago is one of the most isolated the world, hence there are many endemic species. The Northwestern Hawaiian Islands are mostly uninhabited atolls and banks and generally in excellent condition with the only potential threats being coral bleaching and marine debris. The Main Hawaiian Islands have 1.2 million residents and 7 million tourists each year, hence they have been heavily developed with extensive tourism infrastructure; the coral reefs are estimated to be worth US\$10 billion per year to the economy. The major pressures are from land-based sources of pollution, over-fishing, recreational overuse, and alien species. Fishing pressures are a clear difference between the islands, with the remote reefs having healthy populations of large apex predators; whereas these have largely been over-fished off the main volcanic islands. U.S. government funding and expanded partnerships amongst organizations have resulted in more monitoring, mapping, and research efforts to guide management decisions.

**The American Caribbean (Chapter 16):** The reefs appear to have stabilised after massive losses in the 1980s and 1990s, due to coral diseases, bleaching and human damage. However, this stabilisation is at much lower levels of coral cover; therefore there is little reason for optimism. Fishing pressures continue in both the economically 'poorer' regions of Puerto Rico, and the more 'wealthy' coastlines of Florida and US Virgin Islands. The major recent change has been large multinational fishing on the isolated and uninhabited Navassa reef, where the once healthy populations of major target fishes have been massively depleted in just 2 years. Monitoring is demonstrating negative trends in reef community health, especially in existing

MPAs. This is providing a stimulus for better management to protect coastal resources by reducing anthropogenic stresses. An essential need is to strengthen cross-boundary and cross-jurisdictional agreements to facilitate ecosystem-based management and information and technology transfer. Mapping, monitoring, and management of coral reefs of Florida, Flower Garden Banks, Puerto Rico, U.S. Virgin Islands and Navassa have all improved, with increased government awareness and funding.

**Northern Caribbean and Western Atlantic (Chapter 17):** Coral cover in the Northern Caribbean remains low, compared to pre-1960s status, with an average of 20% cover. There are a few sites in most countries with 30-50% coral cover, whereas many other sites have 3-10% cover. There has been little recovery of the formerly abundant *Acropora* coral cover, and diseases, bleaching and pollution are still occurring. Patchy recovery of *Diadema* (sea urchin) is occurring, but algae still dominate many reefs. Fishing is still intense; some grouper populations are virtually extinct, and it is rare to see large fishes on the reefs in many countries. There have been improvements in some countries, little change in others and a decline in others e.g. the Cayman Islands. Data were obtained from Haiti for the first time. All countries report significant threats to coral reefs including: over-fishing; land based sources of pollution; and regional or global factors such as coral bleaching and disease. Over-fishing of algal grazing fishes is the major cause of macro-algal overgrowth of corals. National capacity to implement and enforce fisheries regulations is inversely proportional to fishing intensity. Most countries have adequate legislation, but enforcement is inadequate or lacking, and many MPAs lack adequate management. Although progress in coastal management is being made in most countries, poor financial resources often impede the implementation of laws and policies.

**Central or Mesoamerica (Chapter 18):** Natural disturbances, such as hurricanes, coral diseases, *Diadema* mortality, and coral bleaching, and anthropogenic stresses, such as nutrient enrichment, sedimentation, over-fishing, and direct damage due to marine activities all threaten the coral reefs. A new regional initiative between Belize, Guatemala, Honduras and Mexico, has gathered considerable support for public and private conservation efforts, and resulting in coordinated environmental monitoring of coral reefs, which is starting to produce trend data. NGOs are active in the region and assisting communities with co-management of their resources to reverse major declines in fisheries stocks. Tourism is expanding very rapidly and will have positive effects in providing alternative uses for coral reefs and employment for communities, but the rapid and often uncontrolled pace of development is damaging coastal lands and increasing demand for quality seafood e.g. lobsters and groupers.

**The Eastern Antilles (Chapter 19):** The coral reefs of the French West Indies and nearby islands have steadily, but slowly, declined since the early 1980s. This has stimulated a long-term monitoring on the French islands and increased Reef Check activities in the other island states with the support of the UNEP Regional Coordinating Unit in Jamaica. Reef Check rapid assessments are to fill gaps where there were no current data, and to train local fisheries and dive operator staff. All reefs face a common set of threats: high rates of sedimentation, due to deforestation and bad land management, which affect mainly the reefs in the enclosed bays; algal proliferation due to an overload of nutrients in the coastal waters from excessive use of fertilizers and poor wastewater treatment; and chronic over-fishing and harvesting of reef resources. More MPAs have been declared, but many remain without adequate management. Many of these islands were impacted by a series of major hurricanes in mid-2004; and there are

no available data on the fate of the reefs, however it is anticipated that many sustained wave and sediment damage.

**Southern Tropical America (Chapter 20):** Most coral reefs in the region have undergone major changes in the last 30 years, but particularly during the 1980s. There have been considerable losses of live coral cover in many reef areas, while algae have become dominant. However, some areas of high coral cover occur on both the Caribbean (means between 20-40%) and Pacific (means above 40%) coasts. The coral reefs are strongly influenced by continental runoff containing large amounts of sediments and high concentrations of nutrients from some of the largest rivers in the world. The other major threats are coral bleaching, disease outbreaks, phytoplankton blooms, and direct human pressures from deforestation, increased sedimentation, coastal development, sewage pollution and over-fishing. An additional threat is due to the demands of a strongly developing tourism industry for seafood. There are major gaps in financial support for coral reef monitoring and management, and governments are not fully aware or concerned about the fate of their coral reefs.

**Reviewers:** Jon Day, Lyndon De Vantier, Jeremy Goldberg, Stefan Hain, Gregor Hodgson, Ian Miller, Russell Reichelt, Bernard Salvat, Posa Skelton, David Souter, Robin South, Chris Thompkins, Marjo Vierros and Carden Wallace



## OKINAWA DECLARATION ON CONSERVATION AND RESTORATION OF ENDANGERED CORAL REEFS OF THE WORLD

Coral reefs and associated ecosystems are invaluable human treasures. They support the most diverse marine communities and beautiful seascapes on the planet, and provide wave-resistant structures and resources for local communities, fisheries, and tourism. However, coral reefs and associated ecosystems are now under serious threat of collapse because of over-fishing, development of the coastal zone, including dredging and landfill, and terrestrial run-off. Moreover, the increase in sea surface temperatures, the decrease in carbonate levels as well as sea-level rise, caused by increasing anthropogenic CO<sub>2</sub> in the atmosphere, all act synergistically to stress coral reefs, which lead to severe bleaching and extensive coral mortality. The degradation of coral reefs by local, regional, and global environmental stresses is at the very least destroying the health, function, and positive values associated with coral reefs, and at the worst leading to loss of this treasure.

We, the participants of the 10th International Coral Reef Symposium (28 June to 2 July, 2004, Okinawa, Japan) acknowledge that the degradation of coral reefs worldwide has now reached a critical stage. We declare in the strongest terms that additional destruction of coral reefs must be avoided and more effort is necessary to prevent further reef demise. Conservation and restoration of coral reefs should be made without delay in each nation acting individually and in concert through closer international cooperation. To this end, we advocate scientific research and rigorous monitoring, management-tool development, and appropriate measures for conservation and sustainable use of coral reefs. In addition, scientifically sound restoration measures for already-degraded coral reefs must be applied.

A twin strategy must be taken over the longer term to reduce human induced climate change by reducing green-house gases, but at the same time a reduction in CO<sub>2</sub> must be matched by action to reduce immediate threats of declining water quality because of land-use changes and pollution, and mass exploitation of fish biomass. To achieve these goals, we recommend four key strategies: 1) achieve sustainable fishery on coral reefs, 2) increase effective marine protected areas on coral reefs, 3) ameliorate land-use change impacts, and 4) develop technology for coral reef restoration. Such efforts must be fostered and sustained through stewardship and cooperation among scientists, managers, policymakers, non-governmental organizations, and the general public. The task must be enhanced through international linkages among the principal global scientific body (International Society for Reef Studies [ISRS]), the main international management initiative (International Coral Reef Initiative [ICRI]), as well as leading international organizations (e.g. UNESCO, UNEP, IUCN) and NGOs.

As participants in the 10th International Coral Reef Symposium, we collectively appeal to all researchers, managers, users, and lovers of coral reefs to accomplish the above tasks, and we urge relevant international organizations, national governments, and NGOs to find common understanding and means to collaborate towards this goal. Approved 02 July 2004 by acclamation.



## **ACTION STATEMENT FROM 2ND INTERNATIONAL TROPICAL MARINE ECOSYSTEMS MANAGEMENT SYMPOSIUM (ITMEMS2)**

The first International Coral Reef Initiative (ICRI) Workshop was held at Silliman University, Dumaguete City, Philippines in May 1995 to consider management action to halt and reverse the decline in the world's coral reefs.

At that meeting, ICRI recognized the following important principles for management of coral reefs and related tropical ecosystems:

- involving the full participation and commitment of all stakeholders in true partnerships;
- supporting actions that will have tangible, positive and measurable effects;
- managing human activities because these are the major causes of coral reef degradation;
- recognising the diversity of cultures, traditions and governance within countries;
- using Integrated Coastal Management with community participation for ecosystem management;
- developing national capacity to conserve and sustainably use the resources by long-term commitment;
- integrating strategic research and monitoring programs; and
- using the extensive body of appropriate international agreements and organisations.

The ICRI Call to Action, and Framework for Action were formulated by 110 participants from 40 countries. The Call focussed on 4 themes: Integrated Coastal Management; Capacity Building; Research and Monitoring; and Review and Performance Evaluation. The Framework identified global priority actions within each of these themes. ICRI recognised the need for regional and national initiatives and coordination to implement priority actions.

Specifically ICRI recommended actions by all relevant parties for coral reefs and related tropical ecosystems that:

- support ICRI and the Framework for Action at international, regional and national levels;
- support national and regional efforts to establish and coordinate strategies, priorities and programs to implement the ICRI Framework for Action;
- ensure that sustainable management is considered at relevant international meetings;
- develop and strengthen national, regional and international mechanisms for sustainable management;
- promote access to financial and technological resources to better inform governments, industries and communities; and
- address conservation and sustainable use of coral reefs and related ecosystems e.g. mangrove forests and seagrass beds.

In November 1998, ICRI convened ITMEMS1 in Townsville, Australia (300 attendees from 49 countries) to review progress of the Call to Action and provide a specialist forum to identify the lessons gained from experience with coral reef management projects. ITMEMS1 endorsed the Call to Action and issued an updated Action Statement of priorities.

The Action Statement Recommendations for Coral Reefs and Related Ecosystems was produced at ITMEMS2 in Manila, Philippines in March 2003 by 200 attendees from 36 countries. The Recommendations were:

**Integrated Coastal Management (ICM) and Marine Protected Areas (MPAs):** large-scale, ecosystem-based management is essential to halt and reverse the decline in coral reefs. Coordinated management is required to: mitigate stresses; protect biodiversity; recognise the concept of 'connectivity'; and develop networks of ecologically connected MPAs, incorporating no-take areas to protect biodiversity and contribute to sustainable fisheries management. The principle of coral resilience to bleaching should be included in MPA and ICM design. Countries and the global community should recognise that local community-managed MPAs are essential to incorporate the major social, cultural and economic factors in planning and management. In providing for management of coral reefs and related ecosystems, these MPAs should: include transparency of all processes; develop partnerships between the community and private sector for sustainable funding; and use multi-lateral instruments to leverage cooperation across boundaries. Countries should develop targets to protect ecological processes, habitats and biodiversity through MPA networks and ICM.

**Co-management:** the importance of full participation and involvement of local resource users and indigenous people has not been fully recognized, but it is essential for ICM. Co-management partnerships that are flexible and involve a variety of stakeholders, especially local subsistence users, are key mechanisms for successful community participation. This is particularly important in small, localised MPAs, where better recognition of community social values and the promotion of sustainable livelihood strategies are possible.

**Achieving Sustainable Fisheries:** reef fisheries are already seriously over-exploited in many places, thereby threatening food security and livelihoods of coastal communities. Demonstrably sustainable fisheries management requires the use of relevant international fishery instruments and organisations involved in trade, enforcement and equity issues to maintain reef productivity and biodiversity. Major tools include the establishment of effective no-take MPAs, protecting fish spawning aggregations, and encouraging sustainable mariculture to reduce the take of wild fish as juveniles or for feed. Monitoring is essential to set directions for action, provide feedback to communities, identify trends, provide data for adaptive management and evaluate management performance.

**Coral Bleaching:** the risk of bleaching should be factored into the design and management of MPAs by including evidence of coral resistance and resilience, and ensuring that plans remain flexible. Managers, scientists and policy-makers need current information on the extent and severity of bleaching and subsequent recovery. They should be prepared to act as advocates for policies aimed at mitigating the negative effects of climate change.

**Restoration and Rehabilitation:** reduction of damaging practices to accelerate natural recovery processes is essential before resorting to restoration and rehabilitation. Such interventions should only be applied where there is low potential for natural recovery or to protect tourism assets. A network of managers, scientists, practitioners and local communities is needed to share information and develop guidelines, and intervention measures should be evaluated for ecosystem and economic efficiency.

**Role of the Private Sector:** coral reef management involves all local, national and international stakeholders within formal and informal economies that use, impact, extract and exploit coral reef resources. Active engagement with the private sector is therefore critical to maximize the benefits for local users, with measures including partnerships between the public and private sector in marine conservation e.g. ecotourism, aquarium fish trade, pharmaceutical companies etc. Governments can create incentives (and remove disincentives) for private investment through policies and legal and institutional mechanisms for sustainable resort construction, waste management, dive operations, and promotion of international labeling of best practice examples.

**Enforcement:** governments, funding agencies and NGOs need to recognise that strong enforcement of regulations is essential for effective MPA management. This should involve local communities and marine managers being provided with greater financial and political support and a direct role in resource management. Moreover the judicial system should apply penalties that match the damage caused by marine resource criminals. MPA and ICM planning should include adequate enforcement with fines and penalties set at true deterrent levels, rather than being considered as a cost of 'doing business'. MPA and ICM managers need to be provided with examples of effective enforcement mechanisms.

**Capacity Building and Sustainable Financing:** appropriate long-term sustainable funding, including 'Debt-for-Nature Swaps', is needed for effective management. Potential mechanisms include secure trust funds, endowments, small grants programs, MPA user fees, conservation concessions, and supplemental livelihood initiatives to link community well-being with improvements in ecosystem health.

**Training/Awareness:** a lack of human capacity and awareness of coral reef values and threats is the greatest impediment to effective management. Therefore increased training is required for legal institutions, government officials, resource users and NGOs in ICM and MPA management and enforcement. Partnership agreements are needed to ensure accountability and enhance community participation in resource management.

**Networking/Partnerships:** an increase in information exchange through mechanisms such as peer-to-peer exchanges, good practice demonstration sites, partnerships across disciplinary, jurisdictional and cultural boundaries, and capacity building is required. Partnerships also avoid donor competition and facilitate private sector and community investment, and include NGOs in management.

**Research and Monitoring Programs:** these are essential for biodiversity and natural resource management, but they require continued commitment to high quality research and monitoring to support decision-making. Such programs should be based on globally accepted protocols. They are most successful when they involve and respect the knowledge and skills of user communities, scientists, and the public. Long-term multi-disciplinary ecological and socioeconomic monitoring is essential to identify emerging issues, and determine whether long-term trends result from human disturbance.

**Information Coordination and Dissemination:** conservation measures can fail because of a lack of awareness by managers. Summaries of relevant projects should be available to managers and stakeholders on ReefBase, FishBase etc. Data and information should be managed centrally with guidelines for data storage, security and formats. Non-sensitive data could be publicly available on websites and in traditional libraries in digital and hard copy formats, and developed into a global inventory of tropical marine ecosystem information systems.

**Communication:** effective management and enforcement requires awareness of objectives and the responsibilities and rights of resource users. All projects need carefully planned and funded communication programs that are responsive and culturally relevant. Such programs include educational activities from pre-school to specialised professional courses.

**Review and Performance Evaluation:** effective management depends upon good information and reviewing the effectiveness of achievement of management objectives. These should be based on stakeholders setting performance targets and developing evaluation systems to ensure acceptability, reliability, compatibility, and conformity to indicators, and processes. Monitoring and performance evaluation systems should be developed in the context of resources for management and it was suggested that this would require 5-15% of the management budget.

# ÉTAT DES RÉCIFS DANS LE MONDE EN 2004

BERNARD SALVAT

Version très abrégée et très adaptée de *l'Executive Summary* de Clive Wilkinson  
*Status of Coral Reefs of the World: 2004*

## 1. RÉSUMÉ DE LA SITUATION DES RÉCIFS CORALLIENS EN 2004

### Une situation préoccupante pour les récifs coralliens.

- En 2004, on estime que 20% des récifs du monde ont été détruits et qu'ils ne montrent aucun signe de récupération.
- Les rapports indiquent que 6.4% des 16% de récifs endommagés par les phénomènes de blanchissement et mortalité des coraux en 1998, ont totalement récupéré ou sont en cours de récupération.
- Les rapports permettent d'indiquer que 24% des récifs dans le monde sont actuellement en grave danger de destruction sous les impacts des activités humaines et que 26% le sont également dans l'avenir.
- Les récifs continuent à se dégrader en raison des pressions humaines croissantes. De mauvaises pratiques culturelles dans les bassins versants provoquent une pollution par les sédiments, les nutriments et autres produits toxiques qui atteignent les récifs.
- La sur pêche, et particulièrement les méthodes destructives de pêche, déstabilisent les récifs et diminuent leur productivité. Conjointement aux autres pollutions et dégradations, on assiste à un changement de nature des récifs qui sont alors dominés par les algues au détriment des coraux constructeurs.
- Les ravages de prédateurs des coraux, comme l'étoile de mer épineuse, et les épidémies semblent stabilisés ou même en diminution bien que des dommages soient importants sur certains récifs.
- L'état des récifs dans les Caraïbes n'a plus rien à voir avec ce qu'il était 30 ans auparavant. Les communautés coralliennes ont été décimées à plus de 80% dans beaucoup d'aires récifales, mais des signes de récupération se manifestent dans certains récifs.

- Dans le sud est asiatique et l'Océan Indien où les récifs sont au maximum de leur diversité, il y a peu de signes positifs de récupération des récifs alors que la pression humaine s'accroît.
- En Australie et dans le Pacifique, les récifs demeurent en relative bonne santé.

### **Les menaces globales exceptionnelles sur les récifs coralliens**

- Après les phénomènes de blanchissements mortalités des coraux de 1998 (El Niño-La Niña) les récifs continuent de récupérer dans des aires récifales bien gérées ou isolées. Ailleurs, les situations sont plus diverses.
- Des phénomènes localisés de blanchissements ont été observés en 2000 et 2003 mais sans commune mesure avec ceux de 1998 qui étaient à très large répartition.
- Le blanchissement quasi mondial de 1998 est considéré comme un événement majeur à l'occurrence millénaire. Des prédictions de changement climatique permettent de considérer que de tels événements pourraient être plus fréquents dans les décennies à venir.

### **Une meilleure gestion et une plus grande prise en compte des récifs et de leurs ressources par les décideurs, les acteurs et leurs partenaires.**

- Sur la Grande barrière d'Australie, les surfaces des zones protégées sont passées de 5 à 33% à la suite d'études scientifiques et après consultation de tous les partenaires intéressés.
- Le sommet mondial du développement durable de 2002 a appelé à la constitution d'un réseau mondial des aires marines protégées et à des efforts internationaux pour réduire les pertes de biodiversité, y compris dans les récifs coralliens. Les plus importantes ONG de conservation s'emploient ensemble à cette tâche.
- Certaines ONG ont développé des méthodes rapides d'investigations pour sélectionner les sites à protéger de toute urgence. Elles ont par ailleurs élaboré des outils pour les gestionnaires concernant la conservation des récifs dans la perspective des changements climatiques globaux.
- L'Initiative Internationale pour les Récifs Coralliens (ICRI) et ses actions sont de plus en plus prises en compte par les politiques qui manifestent une réelle volonté d'action en faveur des récifs. La situation des récifs coralliens est maintenant évoquée dans les principaux forums internationaux.
- Les récifs de profondeur dans les eaux froides sont maintenant reconnus comme en danger par les chalutages profonds et justifient des mesures de protection.
- Des millions d'individus ont été sensibilisés aux récifs coralliens par le film Nemo, mais les conséquences sur les stocks de poissons tropicaux d'aquarium ont été néfastes.

## **2. ÉVOLUTION DE L'ÉTAT DES RÉCIFS CORALLIENS DEPUIS 10.000 ANS**

Il y a quelque 10.000 ans, débutait l'histoire des récifs coralliens modernes, à la fin de la dernière période glaciaire alors que le niveau de la mer était 110 à 120 mètres plus bas qu'actuellement. Les récifs qui s'étaient construits auparavant étaient à cette époque des collines de calcaire couvertes par des forêts tropicales. Ce bas niveau des océans permit de nombreuses migrations humaines vers des terres jusqu'alors inhabitées. Le niveau des océans s'éleva de 240 cm par centaine d'années (les prédictions d'élévation sont actuellement de 50 cm) et les récifs

s'édifièrent et prospérèrent sur leurs prédécesseurs. Les populations humaines primitives apprirent à exploiter les ressources de ces récifs comme le prouvent les fouilles archéologiques qui démontrent des récoltes importantes de poissons, de coquillages, de mammifères et plus particulièrement de tortues par les habitants d'alors. Cette exploitation s'est développée à mesure que les populations humaines augmentaient et que leurs techniques s'amélioraient.

Il y a 1000 ans, presque toutes les régions bordées par des récifs coralliens étaient habitées par l'espèce humaine à l'exception de quelques îles isolées de l'Océan Indien et du Pacifique central. Ces populations vivaient des ressources des récifs pour leur alimentation comme pour les matériaux de construction nécessaires à leurs habitations. Ces récifs étaient sans doute en excellente santé avec des coraux florissants, des communautés bien structurées de poissons et d'invertébrés, mais probablement avec des stocks diminués pour des espèces prisées de grande taille et de récolte facile : tortues, dugongs et lamantins, bénitiers. Les populations riveraines des récifs étaient peu nombreuses, tout particulièrement sur les plus petites îles dans lesquelles une gestion traditionnelle s'était mise en place afin d'assurer la pérennité des ressources.

Il y a 100 ans, la situation était à peu de choses près inchangée comme s'accordent à l'indiquer les rapports des 17 réseaux régionaux du GCRMN qui avaient à se prononcer à ce sujet. Le recouvrement des récifs en corail était élevé avec des populations normales de poissons.

Il y a 10 ans, en 1994, le constat s'imposait d'une certaine dégradation et sur exploitation des ressources. Cette date a été choisie car elle marque la naissance d'une action internationale en faveur des récifs, l'ICRI et la nécessité de mettre en place le réseau mondial de surveillance du milieu corallien, le GCRMN. Ces initiatives suivaient les recommandations du sommet Mondial de l'Environnement, Rio 1992, et du 7<sup>ème</sup> symposium international sur les récifs coralliens qui mirent en exergue des considérations alarmantes sur le devenir des récifs coralliens à l'échelle de la planète. ICRI fut lancé en 1994, et le GCRMN en 1996. Le premier bilan mondial des récifs coralliens a été publié en 1998; il résumait essentiellement les informations présentées au 8<sup>ème</sup> symposium international sur les récifs coralliens à Panama.

Le Réseau REEF CHECK, partenaire du GCRMN, a développé ses programmes de surveillance des récifs par des volontaires bénévoles dans 70 pays parmi les 101 qui comptent des récifs coralliens sur leur littoral. Les équipes ont fait le bilan de plus de 750 récifs en 2003 et les résultats montrent qu'en général les récifs de coraux détruits lors des blanchissements de 1997-98 ont récupéré. Toutefois, le nombre d'indicateurs relevant des activités humaines sur les récifs, comme les ressources alimentaires, continuent de diminuer. Par exemple, le nombre de sites sans aucun représentant de mérous dans les Caraïbes ou de napoléon dans l'Indo-Pacifique est passé de 90 à 95% de 1997 à 2003. Considérant 18 index relevant des activités humaines dans les récifs coralliens, Reef Check met en évidence que les formations coralliennes d'Australie et des îles du Pacifique sont les moins endommagées. Un index synthétique a été défini à cet égard afin de faciliter les comparaisons entre régions. À l'inverse de l'Australie et des îles du Pacifique qui présentent les index les plus élevés, ceux du Golfe Arabique, des Caraïbes et de l'Asie du sud-est sont les plus faibles et dénotent d'importants impacts humains négatifs sur les récifs.

En 2004, la situation des récifs coralliens dans le monde, enrichie des éclairages du passé, permet de dégager trois recommandations générales et essentielles pour leur conservation.



Il est urgent de réduire les impacts des activités humaines sur les formations coralliennes. Il est impérieux de lutter contre les causes des changements climatiques globaux dont les effets provoquent des dégradations considérables. Il est indispensable de pourvoir aux besoins en ressources humaines et financières des petits pays afin qu'ils gèrent durablement leurs ressources récifales. Si ces recommandations sont suivies d'effets, un avenir optimiste peut être de mise pour les récifs coralliens. Si tel n'est pas le cas et si les choses continuent, il est à craindre que beaucoup de récifs coralliens ne soient plus viables et n'assurent plus les services et les ressources dont bénéficient des millions de personnes, situation qui correspondra également à une grande perte de biodiversité.

### **3. GRANDE BARRIÈRE D'AUSTRALIE ET RÉGION CARAÏBE: UN EXEMPLE DE CONTRASTE ENTRE DEUX RÉGIONS**

Deux régions coralliennes peuvent être mises évoquées pour des raisons opposées: la Grande barrière d'Australie et la région Caraïbe.

En Australie, des initiatives capitales ont été prises en faveur de la conservation des récifs après la décision du parlement de voir un tiers de la Grande Barrière protégée comme zone de non prélèvement (no-take zone) en incluant surtout des écosystèmes associés (mangrove, herbiers...). Néanmoins une controverse est apparue sur l'intérêt ou non des zones ainsi protégées pour les pêcheries. Les autorités nationales et internationales responsables de la pêche demandaient qu'il soit scientifiquement établi que de telles aires protégées soient bénéfiques pour les pêches des secteurs périphériques, avant que celles-ci ne soient décidées.

À l'inverse de cette bonne nouvelle, il convient de remarquer la dégradation catastrophique des récifs des Caraïbes. Cette situation est due aux phénomènes de blanchissement-mortalité des coraux et aux épidémies, conjointement aux cyclones et à la pollution chronique due aux activités humaines comme la sur pêche, l'enrichissement en nutriments, la pollution terrigène, etc. Le Centre de recherche sur la diversité biologique de San Francisco a introduit une demande auprès du gouvernement des États-Unis demandant que des espèces de coraux en danger (*Acropora*) des Caraïbes soient protégées dans le cadre fédéral de l'Endangered Species Act (ESA); une décision devrait être prise en mars 2005. Une étude de l'Université d'East Anglia en Grande-Bretagne a démontré l'étroite corrélation dans l'espace et dans le temps (de 1983 à 2000) entre l'élévation de température et les phénomènes de blanchissements. Une augmentation de 0.9°C est suffisante pour le déclenchement du phénomène, ce qui est inquiétant lorsque l'on sait que la prédiction d'élévation de la température des eaux dans les Caraïbes pour la fin du siècle est de 1.0°C.

### **4. MENACES SUR LES RÉCIFS**

Les causes naturelles de stress et de dégradations des récifs coralliens sont généralement bien supportées par ces derniers qui récupèrent après les effets de cyclones, d'inondations côtières par des eaux douces, de tremblement de terre et d'éruption volcanique ou encore de faibles niveaux d'épidémie atteignant certaines populations animales des récifs. La crainte quant à l'impossibilité de récupération des récifs après de tels événements naturels, tient à leur faiblesse à la suite de dégradations anthropiques. La même crainte est formulée lorsqu'il est prédit que les événements naturels interviendraient à une plus grande fréquence avec les changements climatiques globaux. C'est ce que prévoit certains scénarios à propos des tempêtes tropicales qui augmenteraient en fréquence et en intensité ou encore relativement à d'importants changements des grands courants marins

Les causes anthropiques dégradant les récifs coralliens ont été traitées et développées en détail dans les «États des récifs du Monde» des éditions précédentes. De plus, ces causes sont exposées dans les chapitres relatifs à l'état des récifs dans les réseaux régionaux. Il s'agit de prélèvements inconsidérés de la faune ou de matériaux coralliens, souvent avec des méthodes destructives. Il s'agit également des pollutions de toutes sortes et particulièrement de l'enrichissement des eaux côtières en nutriments et en substances toxiques, ou encore des effets néfastes des sédiments amenés par les rivières. Il s'agit aussi de destruction de l'habitat corallien lors de la construction de ports et d'aérodromes, de remblaiement de zones coralliennes et lagonnaires frangeantes, éventuellement d'échouages de bateaux sur les récifs.

La troisième catégorie de causes dégradant les récifs coralliens est l'objet de controverses. Il s'agit de causes naturelles, mais qui sont probablement exacerbées par les activités humaines. Il en est ainsi des événements en relation avec les changements climatiques globaux comme les phénomènes de blanchissement ou encore de la diminution du potentiel de calcification des coraux en rapport avec l'augmentation de la concentration en CO<sub>2</sub> dans l'eau de mer. Il est aussi question des épidémies atteignant les coraux ou d'autres organismes des récifs, ou des espèces invasives qui perturbent l'équilibre écologique en entrant en compétition avec des espèces locales.

Enfin, une dernière raison de la dégradation des récifs, tient à une gouvernance non éclairée et à une faible volonté politique d'intervention dans beaucoup de pays et au sein des agences internationales, même si cela est le fait d'inadvertance.

## **5. LES CHANGEMENTS CLIMATIQUES GLOBAUX ET LES RÉCIFS CORALLIENS**

La cause la plus importante de dégradation des les récifs au cours de la dernière décennie a été la mortalité des coraux lors des phénomènes de blanchissements, spécialement à l'occasion d'événements El Nino / La Nina. Lors du blanchissement de 1998, 16% des récifs ont été détruits, en majeure partie dans l'Océan Indien et le Pacifique ouest. Il est maintenant établi qu'il s'agissait d'un événement à échelle millénaire. Des colonies coralliennes de plus de 1000 ans sont mortes dans plusieurs régions. On peut être inquiet des prédictions selon lesquelles de tels événements sont susceptibles de se reproduire bien plus fréquemment dans les cinquante ans à venir.

De nombreux récifs, atteints lors blanchissements de 1998 avec des mortalités de 90% ou plus de recouvrement en coraux, ont montré une remarquable et rapide récupération. Ce fut le cas dans les régions suivantes : Golfe persique, Afrique de l'Est, Seychelles, Maldives, Palau, Japon et Grande Barrière d'Australie. Cette récupération s'accompagne d'un changement des espèces coralliennes dominantes, les espèces branchues étant souvent remplacées par des espèces massives plus résistantes.

Plusieurs mécanismes peuvent être évoqués pour que les récifs coralliens s'en sortent face aux conséquences probables des changements climatiques globaux. La possibilité d'expansion des récifs vers de plus hautes latitudes est peu probable en raison de conditions d'énergie lumineuse insuffisantes en période hivernale pour les algues symbiotiques qu'hébergent les coraux constructeurs de récifs. Mais, par ailleurs, les coraux seraient peut-être en mesure de s'acclimater à des températures plus élevées par sélection de leurs symbiotes mieux adaptés.

## 6. NOUVELLES INITIATIVES EN FAVEUR DES RÉCIFS CORALLIENS

### **Gestion des récifs et aires coralliennes protégées.**

D'importants progrès ont été accomplis dans ce domaine depuis 5 ans par la mise à disposition d'outils performants pour évaluer l'état des récifs, leur importance patrimoniale et culturelle, leur intérêt social et économique et par la création de nouvelles aires protégées. La récente décision de protéger à 33% la Grande Barrière de Corail d'Australie est un élément fort et majeur, de même que pour les Hawaï par les États-Unis. Conservation International, The Nature Conservancy et le WWF ont groupé leurs efforts pour la création d'aires protégées et le sommet mondial de Johannesburg a recommandé la constitution de réseaux internationaux. Mais, l'engouement pour la création d'aires protégées ne doit pas faire oublier qu'elles ne servent à rien si elles ne sont pas correctement gérées et que les réglementations n'y sont pas appliquées. Par ailleurs elles ne règlent pas les dégradations croissantes dans les zones non protégées. Il faudrait éviter que les zones protégées ne soient considérées comme des «réserves de musées» avec l'assentiment inconscient que tout le reste peut disparaître sans inconvénient.

Des programmes ont vu ou voient le jour par les partenaires de l'ICRI : CORDIO pour l'Océan Indien (Suède et Banque Mondiale), associé depuis peu à l'Asie du sud (IUCN), AFD-CRISP pour le Pacifique sud (France, Agence Française de Développement), PEMSEA pour l'Asie de l'est et du sud est (12 gouvernements).

Les récifs profonds en eaux froides, menacés par les chalutages en haute mer, ont été pris en compte par l'ICRI, et sont maintenant l'objet d'une attention particulière pour leur sauvegarde et la biodiversité qu'ils représentent. On peut toutefois regretter que l'ICRI se s'intéresse pas davantage aux écosystèmes associés aux récifs coralliens, comme les mangroves, alors que cet objectif figurait dans l'intitulé de sa création.

### **Recherche scientifique**

Les recherches appliquées à la conservation se sont développées et sont en plein essor, qu'il s'agisse de méthodes pour établir des bilans d'état des récifs, de leur surveillance et d'efficacité des mesures adoptées pour leur gestion, ou qu'il s'agisse de travaux sur la capacité des coraux et des récifs à surmonter les effets des changements climatiques globaux (élévations du CO<sub>2</sub> et de la température des eaux océaniques). Les index de biodiversité sont l'objet d'une attention grandissante de la part de la communauté scientifique. Les études sociales et économiques sur les populations humaines et les ressources des récifs se sont développées qu'il s'agisse des produits consommés localement ou des exportations dont certaines menacent des stocks d'espèces cibles (poissons vivants pour la restauration, marché de l'aquariologie...).

### **Sensibilisation sur les récifs coralliens**

L'état des récifs et leur devenir incertain est une préoccupation maintenant affichée dans tous les forums internationaux, gouvernementaux et non-gouvernementaux. L'ICRI, créée en 1994 est à la base de cette sensibilisation avec l'active participation des gouvernements, des OG du système des Nations Unies, des ONG et des banques de développement.

## 7. ÉTAT DES RÉCIFS DANS LES 17 RÉGIONS DU RÉSEAU MONDIAL DE SURVEILLANCE.

### **Mer Rouge et Golfe d'Aden (Chapitre 4).**

Ces récifs continuent à être en relative bonne santé car les activités anthropiques dégradantes directes ont été supprimées. Il n'y a pratiquement aucune embouchure de rivière, la pêche est faible bien que des espèces cibles soient pêchées, comme les requins. Le tourisme est localisé sur quelques sites. Navigation, tourisme, blanchissements et fortes populations d'étoiles de mer épineuse sont les principales préoccupations dans la partie nord de la Mer Rouge. La conscience politique de la situation est faible de même que la volonté d'agir pour la conservation. De plus, les capacités humaines pour la surveillance et la gestion sont faibles. Les récifs endommagés en 1998 ont récupéré dans plusieurs endroits.

### **Golfe Arabo-Persique (ROPME Sea Area, chapitre 5)**

Les récifs des côtes de la péninsule Arabique n'ont montré aucune récupération après leur importante destruction lors des blanchissements suivis de mortalités de coraux en 1996 et 1998. L'exploitation pétrolière et des marées noires avaient causé antérieurement des dommages réduits aux récifs. Les récifs à proximité des côtes iraniennes avaient subi des mortalités moyennes dues à des phénomènes de blanchissements alors que les récifs du large étaient demeurés en bonne santé. La nécessité d'agir en faveur des récifs coralliens augmente dans la région et un réseau de surveillance s'est mis en place en 2003.

### **Afrique de l'est (chapitre 6)**

Les récifs continuent à subir les dégradations suite aux activités humaines sur le continent. Les apports de sédiment dans les eaux côtières par lessivage des sols dans les bassins versants est en augmentation de même que la pollution par les nutriments. La sur exploitation des ressources est le fait d'une croissance démographique des populations riveraines. Les gouvernements et les communautés montrent des signes encourageants pour des pratiques en vue d'une gestion durable, y compris l'écotourisme. De nombreux efforts ont été cependant mis à mal par des blanchissements-mortalités lors d'El Nino de 1998. Plusieurs récifs ont vu leurs communautés coralliennes détruites à 80% (particulièrement au Kenya et en Tanzanie). Il est inquiétant de constater que les récifs récupèrent lentement, spécialement ceux qui sont soumis à une importante pression humaine. Davantage de moyens humains et financiers sont nécessaires pour mettre en place une bonne gestion des ressources des récifs, localement et nationalement.

### **Îles du sud-ouest de l'Océan Indien (chapitre 7)**

Les récifs des Comores et des Seychelles récupèrent lentement après les importantes mortalités lors des blanchissements de 1998. Mais les activités humaines ralentissent cette récupération et il n'y a pas assez d'aires coralliennes protégées. Les récifs des îles méridionales (Maurice, La Réunion) demeurent en relative bonne santé lorsqu'ils ont échappé au phénomène de 1998. En revanche, les récifs sous une importante influence humaine déclinent, comme à Madagascar. Davantage de sites sont explorés et surveillés comme Tromelin, Juan de Nova et Europa (France) ou encore Cosmoledo, Assumption et Aldabra (Seychelles). Grâce au financement du GEF et de la Banque Mondiale le nombre de stations de surveillance a considérablement augmenté (44 à 72).

### **Asie du sud (chapitre 8)**

Si les récifs des Maldives, des Chagos, du Sri Lanka et des Laccadives ont récupéré après les blanchissements et les mortalités coralliennes de 1998, il n'y a pas eu d'amélioration de la prise

de conscience de l'importance des récifs ni de la nécessité d'en assurer la conservation. Ceci, à l'exception de l'Inde grâce au développement de recherches, à la publication de nombreux ouvrages et à l'information prodiguée à des décideurs gouvernementaux. La surveillance aux Maldives est insuffisante pour un pays dont l'économie repose sur les ressources des récifs, dont le tourisme. Dans la plupart des pays de la région, les capacités de gestion demeurent faibles et le développement l'emporte largement sur des considérations de conservation environnementale. Il existe néanmoins dans cette région des exemples réussis de gestion et de protection des récifs par des communautés riveraines. Aux Maldives plusieurs zones protégées sont gérées par des complexes touristiques eux-mêmes. La pauvreté des populations a pour conséquence une sur exploitation des poissons, des invertébrés et des matériaux coralliens pour les constructions.

### **Asie du sud-est (chapitre 9)**

L'ouvrage «reef at risk» de 2002 indiquait que 88% des récifs étaient moyennement à hautement menacés par les activités humaines. Les méthodes de pêche destructives et la sur exploitation étaient de loin les activités les plus dégradantes pour les récifs, suivies par le développement côtier ainsi que la sédimentation terrigène et la pollution croissantes. La surveillance de l'état des récifs est importante mais insuffisante pour une région qui est la plus vaste du monde corallien et celle qui présente la plus forte diversité. C'est aussi la région du monde où les populations humaines riveraines des récifs sont les plus importantes. Les capacités de gestion sont toujours faibles dans la plupart des pays de cette région avec plus de considération pour le développement que pour la conservation de l'environnement

### **Asie de l'est (chapitre 10)**

La plupart des récifs endommagés en 1998 récupèrent au Japon, à Taiwan et probablement en Chine. Il y eut cependant des mortalités coralliennes d'environ 50% lors de phénomènes de blanchissements sur certains récifs du Japon en 2001. Une explosion démographique de l'étoile de mer épineuse a été observée dans le sud du Japon alors que la forte sédimentation dans les zones côtières et la sur pêche continuent à être les perturbations majeures pour les récifs. Tous les pays mettent en place des réseaux pour la conservation et la gestion durable des récifs. L'aquaculture de poissons et d'invertébrés des récifs complémente l'exploitation des stocks naturels sur les récifs, mais elle est aussi cause de pollution localisées.

### **Australie et Papouasie Nouvelle-Guinée (chapitre 11)**

En 2002, des épisodes majeurs de blanchissements ont atteint près de 60% des récifs de la Grande Barrière. Quelques récifs près de la côte ont vu leurs communautés coralliennes détruites à 90%, et celles des récifs isolés de Flinders et Holmes, dans la mer de corail, ont été décimées à 95%. En dehors de cela, les récifs de la Grande Barrière et ceux de l'Australie occidentale continuent à présenter une relative bonne santé en raison d'une faible pression anthropique et d'une gestion efficace. Il convient toutefois de noter une explosion démographique de l'étoile de mer épineuse et le développement de maladies dans la partie centrale de la Grande Barrière. La gestion est épaulée par des activités de recherche et de surveillance. En Papouasie Nouvelle-Guinée, contrairement à la situation précédente, il y a peu de surveillance des récifs mais ceux-ci sont considérés en relative bonne santé. On note toutefois une augmentation de la pression de pêche, de la déforestation avec ses conséquences sur les eaux littorales (sédimentation terrigène) et de phénomènes de blanchissement. Les capacités du gouvernement sont réduites, mais les ONG développent des programmes de gestion communautaire avec les populations riveraines.

### **Pacifique sud-ouest (chapitre 12)**

Les récifs sont pour la plupart en bonne santé malgré les phénomènes de blanchissements en 2000-2002. Certains récifs ont complètement récupéré alors que d'autres ne récupèrent pas du tout. Les causes dégradantes des récifs restent les activités humaines et les cyclones. Il en fut ainsi des cyclones de 2002 en Nouvelle-Calédonie, aux Samoa, aux îles Solomon et au Vanuatu. Les autres menaces sont les explosions démographiques des étoiles de mer épineuse et les épidémies atteignant certains organismes des récifs. Pollution et dégradations sont très localisées à proximité des centres urbains et dans les lagons. Plusieurs ONG, locales et internationales, ont aidé les communautés à établir leurs propres réserves coralliennes pour une meilleure gestion des ressources et leur surveillance.

### **Pacifique central et sud-est, «Polynesia mana» (chapitre 13)**

Les récifs coralliens polynésiens du réseau «Polynesia Mana» sont majoritairement en bonne santé et à faible risque pour le futur immédiat. Les récifs sont probablement les moins dégradés du monde et relativement protégés des activités humaines dégradantes. Toutefois, les prédictions des changements climatiques globaux font craindre plus de phénomènes de blanchissements et plus de cyclones. La surveillance se développe avec des programmes déjà en cours dans certains pays et débutant dans d'autres. Les populations riveraines font revivre leur culture en faveur d'une exploitation durable des ressources des récifs. La volonté politique d'agir est plus importante en faveur de la conservation, mais plus d'efforts doivent être déployés pour lutter contre la sédimentation terrigène, les dragages de matériaux coralliens, la pollution par les nutriments et la sur pêche. Dans les îles les plus peuplées, des mesures de conservation et de gestion doivent être prises, faute de quoi les récifs déclineront. Notons que la majorité des récifs sont très isolés et devraient rester en bonne santé. Il y a encore peu de réseau de surveillance à l'exception de la Polynésie française et dans une moindre mesure de Wallis et Futuna. Le tourisme est l'industrie majeure dans ces pays bien que leur éloignement de la clientèle touristique ne les favorise guère. La culture des perles noires est importante en Polynésie française et aux Cook. Les aires coralliennes protégées sont peu nombreuses. Bien que la plupart des pays possèdent de fortes réglementations en faveur d'une bonne gestion des ressources, la volonté politique est souvent défailante quant à leur application.

### **Micronésie (chapitre 14)**

Dans l'ensemble, les récifs sont en bonne santé, bien que ceux de Palau aient subi des dégradations lors des blanchissements de 1998. La pression des activités humaines augmente. Les pays et les territoires sont maintenant intégrés dans plusieurs activités de l'initiative américaine de conservation des récifs, telles que cartographie, surveillance, formation, conservation. Les récifs des Samoa américaines récupèrent après les invasions de l'étoile de mer épineuse, les cyclones et les blanchissements mais les populations de poissons ne se rétablissent pas de façon satisfaisante. L'exportation des «pierres vivantes de récifs» et la pêche en scaphandre autonome sont interdites. On note des progrès quant à la surveillance des récifs dans certains pays et plusieurs aires coralliennes ont été protégées qui montrent une bonne récupération des communautés de coraux et de poissons. Le centre corallien international de Palau, ouvert récemment, coordonne le réseau de surveillance de l'état de santé des récifs GCRMN de cette région micronésienne.

### **Pacifique nord-est américain (chapitre 15)**

Grâce à des moyens financiers importants, les îles Hawaii et associées ont été l'objet de nombreuses activités de surveillance et de cartographie. Les îles du nord-ouest sont



pratiquement vierges et sont protégées dans une nouvelle zone de réserve qui inclue de larges zones à prélèvements interdits. À l'inverse, les formations récifales des principales îles habitées des Hawaii sont l'objet de sur pêche, de pollution par les sédiments et de dégradations dues au développement du tourisme. Les populations de poissons sont plus abondantes dans les réserves qu'ailleurs où elles sont fortement exploitées. Il est urgent de créer d'autres zones interdites à tous prélèvements.

### **Caraïbes américaines (chapitre 16)**

Après les épidémies, les blanchissements et des activités humaines dégradantes des années 80 et 90, les récifs semblent avoir récupéré mais à un niveau moins important en ce qui concerne la couverture corallienne. Les pressions de pêche sont toujours aussi fortes à Porto Rico, mais aussi en Floride et aux îles Vierges. Les récifs isolés et inhabités de Navassa ont été massivement exploités pour quelques espèces cibles de poissons par plusieurs pays. La cartographie des récifs de plusieurs zones et pays a permis de mieux sensibiliser les gouvernements des pays en faveur des récifs. La surveillance de certaines aires protégées indique un certain déclin de leur état de santé. Des projets transfrontaliers seraient à étudier.

### **Caraïbes du nord et Atlantique ouest (chapitre 17)**

Les formations récifales d'accès facile continuent à se dégrader mais moins rapidement qu'avant. De nombreux récifs des Bahamas, de Turks and Caicos et de Cuba sont en relative bonne santé, de même que ceux des Cayman et des Bermudes avec toutefois des dégradations croissantes. Les récifs de la République Dominicaine, d'Haïti et de la Jamaïque présentent un faible recouvrement en coraux et peu de poissons. La dégradation des récifs est due à plusieurs raisons : pollution par les nutriments, sédimentation terrigène, zooties, sur pêche, méthodes destructives de pêche, ancrages des bateaux, développement du tourisme. La dégradation des récifs ne favorise pas l'essor des activités touristiques. Plusieurs pays possèdent des aires protégées qui n'existent que sur les documents.

### **Amérique centrale - Méso-Amérique (chapitre 18)**

L'état des récifs semble stabilisé après les récents dommages considérables dus aux blanchissements, à plusieurs cyclones et aux impacts des activités humaines. Avant ces événements, les récifs Caraïbes de cette zone étaient considérés en bonne santé mais les cyclones de 2000, 2001 et 2002 détruisirent 75% des coraux dans quelques secteurs de Belize. La pression de pêche est très forte. La pollution par sédimentation terrigène et nutriments est importante en raison de mauvaises pratiques culturelles à terre et d'un développement côtier incontrôlé. Cette situation a été prise en compte par le projet Banque Mondiale - GEF en partenariat avec le WWF et autres agences, et dont l'objectif est la préservation des récifs de Belize, Guatemala, Honduras et Mexique. Le projet comportera des activités dans les domaines suivants : surveillance des écosystèmes, systèmes d'informations, renforcement de la gestion des aires protégées, accroissement des capacités nationales et régionales d'interventions en faveur de projets trans-frontaliers.

### **Antilles de l'est (chapitre 19)**

Les récifs des Antilles françaises et îles voisines ont peu à peu décliné depuis le début des années 80. Ceci a provoqué la mise en place d'une surveillance des récifs sur le long terme dans ces îles françaises, de même que des activités Reef Check avec l'aide du PNUE implanté à la Jamaïque. Reef Check a exploré les récifs qui n'ont pas encore été l'objet de surveillance et a organisé des stages de formation pour les responsables des pêches et les clubs de plongée. Les récifs subissent les mêmes atteintes qu'en 2000 : sédimentation terrigène et pollution côtière,



ancrages de bateaux et effets négatifs du tourisme, sur pêche en raison d'une demande accrue, blanchissements, cyclones destructeurs. Plusieurs aires coralliennes ont été récemment protégées mais souvent sans programme de gestion. En 2004, de nombreux récifs de cette région ont subi des cyclones.

### **Amérique tropicale sud (chapitre 20)**

Les récifs coralliens dans les 5 pays de cette zone ont radicalement changé depuis 1980 en raison d'impacts dus aux activités humaines conjointement à des dégradations d'origine naturelle. Le recouvrement en corail vivant des récifs continue de diminuer et ceux-ci sont maintenant dominés par les algues. Toutefois, certains récifs conservent un recouvrement corallien de l'ordre de 20 à 40 % dans les Caraïbes et de 40 % sur les côtes Pacifique. Le Brésil a donné des résultats de surveillance pour la première fois, suite à un programme de 3 années. Des moyens financiers supplémentaires et un engagement plus important des gouvernements est nécessaire pour inverser le déclin des récifs coralliens en créant davantage d'aires protégées et avec une meilleure application des réglementations.

## **8. ACTIONS A MENER POUR LA CONSERVATION DES RECIFS CORALLIENS**

### **CONCLUSIONS ET RECOMMANDATIONS**

Tous les pays possédant des récifs coralliens le long de leur littoral ont été sollicités pour exposer l'évolution de l'état de leur écosystème au cours de la dernière décennie. Il leur était également demandé de donner leurs prévisions sur ce que serait l'état de santé des récifs dans 10 ans, en 1014, selon un scénario pessimiste et un second optimiste.

Les recommandations pour parvenir à un état de santé et de vitalité optimiste pour les formations coralliennes dans le monde sont les suivantes:

- Agir localement et globalement pour réduire les émissions de gaz à effet de serre qui contribuent aux changements climatiques globaux et induisent des destructions massives aux récifs coralliens.
- Revoir les conventions et instruments internationaux et les programmes des agences internationales et régionales relative à l'environnementale quant à leurs objectifs de conservation durable des ressources des récifs.
- Mettre effectivement en application les conventions et accords internationaux et assurer la diffusion des réglementations correspondantes auprès du secteur public
- Aider les petits États et favoriser leur regroupement pour traiter de la conservation et de la sauvegarde des récifs coralliens dans tous les aspects: prise en compte des méthodes traditionnelles et culturelles de gestion, recherche de ressources alternatives à celles des récifs pour les populations, création d'aire protégées, formation et renforcement des capacités humaines d'intervention, aides financières sur le long terme
- Éliminer sinon réduire les activités humaines qui dégradent les récifs coralliens par une gestion intégrée des zones côtières incluant les récifs, tout particulièrement en ce qui concerne la sédimentation terrigène et les eaux riches en nutriments.
- Concourir au rassemblement des forces et des acteurs en faveur des récifs : gouvernement central, secteur privé, secteur associatif, communautés riveraines des récifs
- Intégrer les communautés locales dans les réglementations d'exploitation des ressources récifales et dans la mise en place de nouvelles aires protégées.

- Proscrire les méthodes destructives de pêche et gérer les pêcheries de façon durable.
- Améliorer le rendement des pêches en protégeant des stocks de reproducteur dans des zones protégées et mettre en place des programmes d'élevages pour les «poissons vivants» du marché de la restauration en Asie.
- Créer des aires protégées plus larges capables d'assurer une large distribution de leurs larves à l'extérieur
- Mettre fermement en application les réglementations locales et assurer les poursuites juridiques en cas d'infractions.

## **9. DECLARATION D'OKINAWA ADOPTÉE AU 10ÈME SYMPOSIUM INTERNATIONAL SUR LES RÉCIFS CORALLIENS EN JUILLET 2004**

Déclaration d'Okinawa sur la conservation et la restauration à l'échelle mondiale des récifs coralliens en péril.

Les récifs coralliens et les écosystèmes qui leur sont associés sont des trésors du patrimoine mondial, dont la valeur ne peut être surestimée. Ils sont les représentants des communautés marines les plus diversifiées et des paysages sous-marins les plus beaux de la planète, forment des structures résistant aux vagues et fournissent des ressources pour les communautés locales, les pêcheries et le tourisme. Cependant, les récifs coralliens et les écosystèmes associés sont actuellement sérieusement menacés d'un effondrement en raison de la sur pêche, du développement dans les zones côtières, y compris les excavations et remblaiements, et les apports d'origine terrestre par ruissellement. De plus, l'augmentation des températures de surface, la diminution des concentrations en carbonates de même que l'augmentation d'origine anthropique des concentrations de CO<sub>2</sub> atmosphérique agissent en synergie pour stresser les récifs coralliens, ce qui conduit à des épisodes de blanchissement intense et une mortalité corallienne importante. La dégradation des récifs coralliens due à l'effet d'impacts locaux, régionaux et globaux à tout le moins détruit la santé, les fonctions et les valeurs positives associées aux récifs coralliens, et, au pire conduit à la perte de ce trésor du patrimoine mondial.

Les participants au 10ème Symposium International sur les Récifs Coralliens (28 juin - 2 Juillet, Okinawa, Japon) reconnaissent que les dégradations subies par les récifs coralliens à l'échelle mondiale ont maintenant atteint un stade critique. Ils déclarent de la façon la plus ferme que toute destruction supplémentaire des récifs coralliens doit être évitée et que davantage d'efforts sont nécessaires pour empêcher leur dégradation de se poursuivre. Des mesures de conservation et de restaurations des récifs coralliens doivent être mises en œuvre sans délai, par chaque pays agissant individuellement et en concertation par la mise en œuvre d'une coopération internationale. À cette fin, ils recommandent un effort particulier de recherche, un suivi rigoureux, le développement d'outils de gestion adaptés, ainsi que des mesures appropriées pour la conservation et l'utilisation durable des récifs coralliens. De plus, des mesures de restauration basées sur des résultats de recherche éprouvés doivent être appliquées sans délai aux récifs coralliens déjà dégradés.

Une double stratégie à long terme doit être adoptée pour la réduction des changements climatiques provoqués par les activités humaines, en minimisant d'abord les émissions de gaz à effet de serre. Cependant, une diminution des rejets de CO<sub>2</sub> doit être accompagnée

d'actions visant à la réduction des menaces associées à une dégradation de la qualité des eaux du fait des changements intervenus dans l'usage des sols, des pollutions, et à une exploitation massive des stocks de poissons. Pour atteindre ce but quatre stratégies fondamentales sont recommandées: 1) Parvenir à une exploitation durable des stocks de poissons récifaux, 2) Augmenter le nombre des aires marines efficacement protégées dans les récifs coralliens, 3) Diminuer les impacts résultants des nouvelles pratiques d'utilisation des sols, et 4) Développer de nouvelles technologies pour la restauration des récifs coralliens. Ces efforts doivent être stimulés et soutenus par une coopération entre scientifiques, gestionnaires, décideurs, organisations non gouvernementales et le public. Une telle entreprise doit être favorisée par le développement de liaisons, au niveau international entre le principal organisme de recherche (Société Internationale pour les Etudes Récifales : ISRS), une initiative internationale de gestion (Initiative Internationale pour les récifs coralliens : ICRI), les principales organisations internationales (par ex. UNESCO, PNUD, UICN) et les organisations non gouvernementales.

Les participants au 10<sup>ème</sup> Symposium International sur les Récifs Coralliens en appellent collectivement à tous les chercheurs, gestionnaires, utilisateurs et personnes intéressées par les récifs coralliens pour la mise en œuvre des mesures spécifiées ci-dessus. Ils pressent les organisations internationales appropriées, les gouvernements nationaux et les ONG pour qu'ils trouvent ensemble un terrain d'entente commun et les moyens de collaborer à la poursuite de ces objectifs.

## **10. QUELQUES ACTIONS FRANCAISES EN FAVEUR DES RECIFS CORALLIENS.**

### **L'Initiative Française pour les Récifs Coralliens (IFRECOR)**

L'initiative concerne toutes les collectivités françaises outre-mer dans les trois océans. Elle a été lancée en mars 1999, alors que la France assurait le secrétariat de l'ICRI. Elle est sous l'autorité du ministère de l'écologie et du développement durable, d'une part, et du ministère de l'outre-mer, d'autre part.

Un programme national d'action a été adopté en 1999. Il est mis en œuvre par un comité national qui comporte des parlementaires, des socio-professionnels, des ONG, des représentants de différents ministères et des scientifiques.

Le budget de l'IFRECOR au cours des 4 dernières années a été de l'ordre de 2 millions d'euros qui ont été utilisés pour la réalisation de plans d'actions locaux dans les 7 collectivités françaises outre-mer, plan locaux qui s'intègrent dans le plan national. Chaque collectivité outre-mer a mis en place un comité local qui rassemble tous les partenaires concernés par les récifs coralliens, conservation et gestion des ressources: Guadeloupe, Martinique, Mayotte, La Réunion, Nouvelle-Calédonie, Wallis et Futuna, Polynésie française

Au niveau national, ces activités renforcent la sensibilisation du public sur l'importance des récifs coralliens, établissent un réseau de surveillance, organisent des échanges entre les collectivités françaises, tendent à assurer la préservation des récifs et l'exploitation durable de leurs habitats et ressources.

Au niveau international et par sa participation suivie au comité de coordination de l'ICRI, la France entend œuvrer pour la conservation des récifs dans le cadre de coopérations bilatérales

ou multilatérales. La France participe activement au réseau mondial de surveillance du milieu corallien de l'ICRI, le GCRMN : participation des collectivités françaises aux bilans des réseaux régionaux tous les 2 ans, et animation d'un réseau dans le Pacifique est et central, Polynésie française, à partir de la Polynésie française.

Le dernier comité national de l'IFRECOR s'est réuni à Mayotte, Océan Indien, en mai 2004. Se situant au terme du premier programme national de 4 ans, le comité a enregistré les progrès remarquables qui avaient été fait pour la conservation des récifs corallines dans les collectivités outre mer : intérêt majeur des gouvernements quant à l'importance des récifs au plan de la biodiversité et au plan économique, implication croissante des populations locales dans la gestion du milieu récifal et lagonnaire et dans l'exploitation des ressources, mise en place de réseaux de surveillance de l'état de santé des récifs dans toutes les collectivités, création de nouvelles réserves coralliennes

En 2005, un bilan complet des résultats du premier programme national des 4 années passées sera établi qui permettra de définir le second programme national pour 2006-2010

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### **La Fondation d'Entreprise TOTAL**

Créée en 1992, la Fondation d'Entreprise Total pour la biodiversité et la mer a répondu à un souhait du personnel du Groupe de voir l'entreprise s'engager de façon plus visible dans la protection de l'environnement. La préservation des espèces, plus particulièrement dans le domaine marin, y compris sur la frange littorale, a été retenue comme axe principal des actions de la Fondation.

Deux thèmes principaux orientent ses actions :

- La Biodiversité : Le développement de notre civilisation s'est souvent fait au détriment de nombreuses espèces. Des richesses botaniques, animales ou tout simplement génétiques sont en train de disparaître. C'est ce qui a incité la Fondation à s'intéresser dès 1992 à ce thème, en engageant un partenariat avec le Parc national de Port-Cros et le Conservatoire botanique national méditerranéen de Porquerolles.
- La Mer : Une large proportion de la production d'hydrocarbures de Total provient ou transite par la mer. Contribuer à la protection des zones sensibles marines s'imposait donc comme un thème incontournable pour la Fondation d'entreprise Total.

Total a pour objectifs de mettre en œuvre les meilleures technologies disponibles pour concilier ses activités et la préservation de la qualité de l'environnement marin. Mieux comprendre les écosystèmes marins et participer à la réhabilitation de zones dégradées, incluant les récifs coralliens, les zones humides, les aires protégées et l'éradication d'espèces envahissantes, telles sont les missions de la Fondation d'entreprise Total.

En 2002-2003, la Fondation a apporté son soutien à un programme de recherche international, sous la conduite du professeur Bernard Salvat (École Pratique des Hautes Études, Centre National de la Recherche Scientifique, Université de Perpignan), sur la « Biodiversité des

récifs coralliens ». Huit actions bien distinctes ont structuré ce programme dans des contextes biophysiques, culturels, sociaux et économiques, répartis sur la zone intertropicale de l'Indo-Pacifique. Les thèmes suivants ont été abordés : connaissance de la biodiversité ; perception culturelle de la biodiversité ; diversité génétique des espèces récifales ; intérêt économique de la biodiversité ; rôle des aires coralliennes protégées dans le maintien de la biodiversité ; blanchissement des récifs coralliens ; surveillance corallienne et recouvrement naturel ; surveillance des récifs en rapport avec les changements climatiques. Les équipes française et étrangères étaient dirigées par les responsables suivants : P. Bouchet, (Muséum Paris), R. Thaman (University South Pacific), P.Doherty (AIMS, Australie) et S. Planes (EPHE-CNRS, Perpignan France), E. Gomez et A. Uychiaoco (University of Philippines), R. South et P. Skelton (ORI, Samoa and Australia), N. Downing (Cambridge, United Kingdom), Vo Si Tuan (Nha Trang, Vietnam), R. Galzin ( EPHE-CRIOBE, French Polynesia).

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### **L'Agence Française de Développement (AFD) et l'initiative dans le Pacifique sud.**

Cet établissement public dont le capital est entièrement détenu par l'Etat et qui est l'opérateur pivot de l'aide publique au développement de la France a été fondé en 1941. Depuis plus de soixante ans, l'AFD a contribué au développement économique et social dans plus de quarante pays à travers le monde et dans les collectivités territoriales françaises d'outre-mer. Elle fournit un appui financier aux secteurs public et privé dans les domaines des infrastructures, du développement rural et de l'environnement, des services sociaux (santé, éducation) et des systèmes financiers. Elle s'appuie sur des partenariats avec d'autres bailleurs de fonds tels que la Banque mondiale, la Commission Européenne et la Banque Européenne d'Investissement, la Banque Asiatique de Développement ou la KfW. L'AFD héberge le secrétariat du Fonds Français pour l'Environnement Mondial (FFEM), un outil financier analogue au GEF qui facilite la prise en compte des coûts environnementaux dans les projets de développement. Après s'être impliquée dans le financement de programmes environnementaux terrestres tels que la foresterie, l'agriculture de conservation ou les aires protégées, l'AFD, déjà investie dans la gestion des ressources halieutiques, a récemment étendu son champ d'action aux écosystèmes marins en lançant en 2002 l'initiative française pour les récifs coralliens, qui s'est commuée depuis en « initiative pour la protection et la gestion durable des récifs coralliens dans le Pacifique Sud » (CRISP).

Cette initiative portée par la France et ouverte à toutes les contributions. Elle a pour but de développer une vision pour l'avenir de ces milieux uniques et des peuples qui en dépendent, et de mettre en place des stratégies et des projets visant à préserver leur biodiversité et développer dans le futur les services économiques et environnementaux qu'ils apportent tant au niveau local que global. Ce projet, dont le montage technique et financier a été assuré par l'AFD, se déroulera de Janvier 2005 à Décembre 2007. L'initiative est conçue comme un vecteur d'intégration régionale entre états développés et pays en voie de développement du Pacifique. Elle vise à i) combiner activités transversales de réseau et projets de terrain localisés à objectifs de conservation et de développement économique, ii) articuler recherche, aménagement et développement, iii) combiner les apports de disciplines scientifiques diverses, incluant la biologie, l'écologie, l'économie, la sociologie, le droit et l'anthropologie, iv) intervenir sur l'ensemble des thèmes - terrestres et marins - intéressant les récifs (y compris l'assainissement

et la gestion des bassins versants), et v) ne pas créer de nouvelle structure mais apporter des ressources financières à des partenaires déjà actifs et intéressés à développer et consolider leurs activités dans un esprit de coopération régionale.

Le projet s'articule autour de trois composantes. Composante 1 : *Aires marines protégées et bassins versants* - Cette composante concerne le développement des Aires Marines Protégées (AMP) en tant qu'outil de protection et de valorisation de la diversité biologique des récifs coralliens, et de pérennisation des activités économiques liées à ces milieux, et la gestion des bassins versants afin de limiter l'érosion terrestre, néfaste à la survie et au bon fonctionnement des récifs coralliens. Composante 2: *Connaissance, gestion, restauration et valorisation des écosystèmes coralliens*. Cette composante consiste en un appui à la connaissance des milieux afin de mieux protéger, valoriser, voire restaurer la diversité biologique. Elle concernera l'acquisition de données terrestres et marines et le transfert des résultats de la recherche permettant l'évaluation des risques de dégradation des milieux (indicateurs de sur pêche et de suivi des milieux), le développement de filières aquacoles, la valorisation de molécules à activité pharmacologique (sous l'angle bio pharmacologique et juridique), une étude sur la valorisation du potentiel éco-touristique de la région, un état des connaissances sur les interactions entre l'augmentation de la teneur en CO<sub>2</sub> de l'atmosphère et la croissance des récifs, la vulgarisation de techniques de restauration des milieux et la mise en place d'une métabase de données sur les récifs coralliens du Pacifique. Composante 3: *Coordination, capitalisation, communication et vulgarisation*. Cette composante comprendra la mise en place d'une unité de coordination à laquelle sera affecté un assistant technique, ainsi qu'un volet conçu pour l'intégration, la capitalisation et la diffusion de l'ensemble de l'information (données, approches, méthodes et savoirs-faire) acquise dans le cadre de l'initiative. Sur le plan financier, un financement initial dégagé par l'AFD et le Fonds Français pour l'environnement Mondial (FFEM) de 5 millions d'Euros a généré des co-financements de partenaires tels que Conservation International (CI), World Wild Fund for Nature (WWF), la Fondation des Nations-Unies (UNF) et le Ministère des Affaires Etrangères Français pour atteindre un budget global avoisinant les 10 Millions d'Euros sur 3 ans. La mise en oeuvre technique du CRISP permet d'étendre le partenariat à des Organisations Régionales du Pacifique, telles que le Programme Régional Océanien pour l'Environnement (PROE), le Secrétariat de la Communauté du Pacifique (CPS) ou l'Université du Pacifique Sud (USP), des instituts de recherche, tels que le Centre National pour la Recherche Scientifique (CNRS), l'Institut de la Recherche pour le Développement (IRD, ex-ORSTOM), le Centre International de Recherche en Agronomie pour le Développement (CIRAD), l'Ecole Pratique des Hautes Etudes (EPHE) à travers son laboratoire de Moorea (CRIOBE), et les Universités de Nouvelle-Calédonie et de Polynésie Française. Une quinzaine de communautés insulaires sont concernées par le projet, incluant les trois collectivités territoriales françaises : la Nouvelle-Calédonie, la Polynésie Française et Wallis et Futuna, au sein desquelles des actions seront entreprises sous l'égide de l'IFRECOR (Initiative Française pour les Récifs Coralliens). Contact : Dominique Rojat, rojatd@afd.fr. Agence Française de Développement, 20 Rue Monsieur 75007 Paris cedex, et site web de l'AFD, [www.afd.fr](http://www.afd.fr)

# 1. GLOBAL THREATS TO CORAL REEFS: CORAL BLEACHING, GLOBAL CLIMATE CHANGE, DISEASE, PREDATOR PLAGUES, AND INVASIVE SPECIES

JEREMY GOLDBERG AND CLIVE WILKINSON

A series of new and emerging threats to coral reefs has become a focus of attention in recent decades with clear evidence of widespread and even global damage. This chapter focuses on these threats:

- coral bleaching and global climate change;
- diseases of corals and other reef organisms;
- plagues of predators like the crown-of-thorns starfish (COTS – *Acanthaster planci*) and other damaging organisms such as the sea urchin *Echinometra mathei*; and
- invasive species which have been introduced onto new coral reefs.

These threats are in addition to natural stresses that have always existed on coral reefs such as storms, freshwater inundation and seismic and volcanic events. Direct human pressures on reefs have, until recently, been the dominant factors damaging coral reefs through a range of stresses, many of the which can co-occur:

- the delivery of ‘pollution’ from unsustainable land-based human activities such as deforestation, poorly regulated agriculture, and urban and industrial development resulting in the release of excess amounts of sediments and nutrients. This is exacerbated by the release of nutrients and other pollutants from untreated or poorly treated sewage and industrial and agricultural wastes;
- over-fishing and over-exploitation of coral reef fisheries and coral rock and sand resources. Within the last 2 decades there has been an alarming increase in damaging fishing activities involving the use of home made bombs, cyanide and damaging practices such as *muro ami* that involves dropping weighted rocks onto corals to drive fish into set nets; and
- modification and engineering practices such as building of ports, airports and groynes on coral reefs, including the practice of ‘reclamation’, which pours sediments onto shallow areas, displacing sea area in exchange for increased terrestrial amenity.



Coral reefs managers and scientists now suspect that these apparently newer global threats (bleaching, disease and predators) are increasing rapidly in frequency and severity, coincidentally with direct human disturbances. Predator plagues like COTS are increasingly reported around areas of human activities with 2 strong hypotheses advanced: the plagues may be initiated and certainly exacerbated by either over-fishing of key starfish predators; and/or increases in nutrient runoff from the land favours the planktonic stages of the starfish. Coral disease has caused major disruptions to coral reefs in the Caribbean with a range of human disturbances potentially implicated, and there are now increasing reports of similar disturbances from the Indo-Pacific region. Evidence linking severe coral bleaching and mortality to increasing rates of global climate change attributed to rising levels of anthropogenic greenhouse emissions is growing stronger.

Coral reef managers and policy makers urgently need guidance from the research community on appropriate responses to these mounting levels of global stresses. Management has largely been based on controlling the direct pressures of pollution and over-exploitation. There are now urgent questions for researchers: are there linkages between human activities and the increasing reports of global stresses on reefs and if so, how are they manifested and how can they be controlled or at least minimised?

In the 3 previous reports (*Status of Coral Reefs of the World: 1998, 2000 and 2002*), there was a chapter on the major coral bleaching and mortality event of 1998. In the following section we examine the fate of reefs that were severely damaged in that event and examine subsequent coral bleaching events.

## **CORAL BLEACHING AND GLOBAL CLIMATE CHANGE**

### **Summary of Recovery After the 1998 Bleaching Event**

This episode was the largest coral bleaching and mortality event ever recorded on coral reefs globally, with major effects in the Arabian/Persian Gulf, Eastern Africa, throughout the Indian Ocean, in Southeast Asia, parts of the western Pacific and the Caribbean and Atlantic region (Box p 22). Overall, it was estimated that 16% of the world's area of coral reefs was severely damaged; some areas no longer resembled coral reefs. Approximately half of the reefs in the Indian Ocean and around South Asia were reported to have lost most of their living corals. The Status 2000 and particularly the 2002 reports indicated significant recovery of many affected reefs, especially areas that were remote or within well managed MPAs (Table p 9).

### **Summary of Coral Bleaching from 1999 - 2004**

There has been no repeat of the massive global-scale bleaching of 1998 in the subsequent 6 years, although several minor bleaching events have been reported in many regions worldwide. Coral bleaching has also occurred outside the tropics. In mid to late 1999, there was extensive mortality of 28 species of non-symbiotic gorgonians, sponges, ascidians, bryozoans, and bivalves mainly in South-Eastern France. Two symbiotic corals *Oculina patagonensis* (invasive) and *Cladocora caespitosa* (native) bleached because there were prolonged elevated temperatures of 22.0°C to 23.9°C (1.2°C above summer maxima). Similar mortality had been seen in La Spezia, Italy, in September 1997 and August 1998, likely caused by high temperature bleaching and pathogens.

## Middle East

**Bleaching in 1998:** The devastating bleaching damage to virtually all shallow coral reefs in the Arabian/Persian Gulf in 1996 and 1998 is still clearly evident and recovery is slow. There is more recovery on some of the reefs than was predicted at the time indicating that the coral reefs retain a degree of resistance to coral bleaching. Coral cover was reduced to less than 1% on all reefs and with no apparent parent stocks of corals, there were fears of localised extinctions of some species. Recovery is occurring apparently from larvae of corals growing on the deeper water patch reefs off the United Arab Emirates. It is certain that recovery will take many years, with the proviso that there is not a repeat of the conditions that resulted in the 1996 and 1998 bleaching. There has been slow recovery of corals on the Iranian coast after moderate to slight losses in 1998. Bleaching impacts in the Arabian Sea on the Oman coast and in the Red Sea were relatively minor in 1998.

**Bleaching from 1999-2004:** Coral bleaching was recorded in 1999 around Kish, Farur, and Larak Islands on 30% of shallow water (3-6 metres) coral populations in Nay Band Bay, in the northern Gulf. Bleached corals were mostly massive colonies such as *Favia sp.* and *Porites sp.* and typically 70% of each colony bleached. Bleaching was also observed from 1999 through 2003 yet no event was as intense as 1998, with between 1% to 10% of colonies typically being affected (from Mohammad Reza Shokri Bousjein, mohammad.shokri@studentmail.newcastle.edu.au).

There have been a 3 bleaching events in Oman since 1998, all of which appear to have been localised and not resulting in any significant mortality. In June 2000, a survey of coral rich areas in Musandam (Straits of Hormuz) showed that 19% of survey sites had paling or bleaching of at least 10% of all coral, particularly *Platygyra* and other faviids. Observations in the Gulf of Oman during 2002 indicated that bleaching was affecting some genera, particularly *Astreopora* and *Porites* inhabiting shallow (2-3 m) water although little or no coral mortality resulted. Similar assessments of sites in Musandam showed severe bleaching at the mouth of Ghubb Ali River while other sites remained unaffected. Temperatures at the bleached site exceeded 32.5°C for almost a month, while the non-bleached site temperatures remained below 31.5°C. There have been reports of minor, localised bleaching in sheltered areas around Muscat (from Bandar Jissah and Bandar Khayran) in 2004, affecting *Acropora*, *Montipora* and *Pocillopora* in shallow water (down to 3-4 m) but corals inhabiting deeper water remain healthy (from Simon Wilson, simon.wilson@adelphi-env.com).

## Eastern Africa

**Bleaching in 1998:** Africa's coral reefs were severely affected by bleaching and mortality levels varied from <1% in South Africa to 80% or greater on reefs in Tanzania and Kenya. Recovery of affected reefs continues but improvements have been very patchy and hindered by chronic and local threats, including over-fishing, COTS infestations, and repeated minor bleaching events.

**Bleaching from 1999-2004:** Minor bleaching was reported in northern Tanzania and Kenya during 2003. Mortality was generally minimal and in some cases the species that suffered the most bleaching damage in 1998 showed less bleaching than other species, such as *Pocillopora damicornis* and some *Acropora* species. Reefs that had high coral diversity prior to 1998 have recovered to less than one quarter of their previous coral cover. Degraded reefs with low coral cover outside MPAs have generally recovered half to all of the pre-bleaching cover. The highest coral recruitment has been on protected reefs with reasonably healthy stocks of

parent corals nearby. Recovery is higher on shallow reefs than in deeper water and reefs within MPAs have shown better recovery than those outside, especially on Chumbe Island, Zanzibar, and Mombasa Marine Park, Kenya. Most of the new recruits are *Pocillopora* species, with the highest densities of more than 20 per m<sup>2</sup> at Mafia, Tanzania, and Kiunga, Kenya, whereas on most other reefs the range is 1-3 new recruits per m<sup>2</sup>.

### South West Indian Ocean

**Bleaching in 1998:** In the southern Indian Ocean islands of Madagascar, Mauritius and Reunion, most corals recovered immediately after the bleaching and mortality was minor. Recovery and new coral growth on Madagascar is encouraging, but in many areas this recovery merely balances damage from anchors and pollution from the land. The major impacts of this bleaching event were in the Comoros and Seychelles. Reefs in the Comoros appear to be recovering well, for example the corals in the Moheli MPA have recovered about half of their former coral cover (to about 20%) by early 2002, with even better prospects as recruitment was strong in 2002. The situation is less encouraging in the Seychelles with very low rates of natural recovery, even in the protected areas, and most recovery is in deeper water. In Mauritius, the 1998 bleaching event was widespread yet relatively mild. The main cause of bleaching was an increased SST and solar radiation, exacerbated by increased rainfall leading to decreased salinity and increased terrestrial runoff. The synergy of factors is most likely responsible for the observed bleaching. *Acropora* species were found to be more affected on the reef flat yet non-*Acropora* were more susceptible on the reef slope.

**Bleaching from 1999-2004:** There was virtually no bleaching on Rodrigues, Western Indian Ocean, in 1998, probably due to Cyclone Anacelle bringing clouds and strong winds. However in early 2002, there were very warm temperatures, clear skies and calm seas, and a massive fish kill. By early March, extensive coral mortality was observed in shallow waters and all table and branching *Acropora* were dead. Other corals were bleached, however the bleaching was not widespread, occurring in only one third of sites, but in these up to 75% of corals were affected. By 2003 there was some recovery, but there was simultaneous bleaching at sheltered sites with high mortality of branching and tabular *Acropora*. The recovery at damaged sites is encouraging with many new *Acropora* recruits, however exposed sites still had a cover of loose rubble (from Emily Hardman (osp829@bangor.ac.uk), John Turner, Sabrina Meunier and Tracy Clark)

Temperatures along southwest Madagascar remained above 30°C from December 2002 through March 2003, resulting in such severe bleaching of some inner reefs that they were beyond recognition. The outer reefs of Madagascar are more resilient to, and less affected by, bleaching than other reefs, possibly due to hydrological conditions such as the Comoros gyre, which is impervious to unseasonal warm water incursion, and deeper waters upwelling cooler water to the surface, preventing bleaching events. Little evidence of bleaching was seen in northeastern Madagascar in 2000 and reefs are still recovering from the 1998 event. Extensively bleached and dead corals were seen in 2001 along the southeastern coral meadows of the Lokaro lagoon.

### South Asia

**Bleaching in 1998:** Reefs in the Chagos Archipelago in the Indian Ocean suffered up to 95% coral mortality in many areas in 1998 and in the following 2-4 years there was some new recruitment in all reef areas, from reef flats to at least 30 m depth. This is encouraging, but most of the new corals settled on dead *Acropora* tables, which are eroding and collapsing thereby threatening their survival while others settled on reef slopes, which are being damaged by large quantities of mobile coral rubble. In addition, recruits of certain species are settling more

successfully than others, with more *faviids* recruiting now than before the 1998 mortality. The consensus is that recovery will be slow and that there will be a shift in the species composition of the reefs.

Massive corals now dominate the reefs in the Gulf of Mannar, India as the branching forms (mostly *Acropora*) were lost in 1998. There was further bleaching in 2002 that killed many of the remaining non-massive corals. The massive corals also bleached, but most recovered rapidly. There was no serious bleaching in the Andaman and Nicobar Islands in 1998 and most reefs there remain healthy. This is not the case for the reefs of the Lakshadweep Islands, which suffered massive damage in 1998 (Box p 219). However, there are now clear signs of recovery with many small coral colonies settling on the bare reefs.

There have been reports of bleaching in Bangladesh in 2003 as well as 1998.

In the Maldives, the early reports were of almost total devastation across all the atolls, however more recent data show that some of the atolls in the far south escaped most of the major bleaching damage. Most of the other atolls were reduced to 0 to 5% coral cover, from previous cover in the range of 40 to 60%. Most sites show some encouraging signs of recovery, with the species most susceptible to bleaching showing strong levels of recruitment.

Recovery after 1998 on Komandoo Reef in the Maldives is weak and is not predicted to keep pace with sea level rise or rates of bioerosion. There are prospects of local extinction of species if there are repetitive bleaching events (from Karen Loch, Wolfgang Loch, Helmut Schuhmacher (h.schuhmacher@uni.essen.de), and Wolf See)

Recovery in Sri Lanka has been variable. Many small colonies of *Acropora* and *Pocillopora* are evident on the shallow parts of the Bar Reefs, where coral cover had been reduced to very low levels from about 80% prior to 1998. About 14% coral cover has remained in deeper areas (8m depth) on these reefs and probably represent the parent stock for the shallow water recruitment. Coral cover in the Hikkaduwa MPA has increased from 7% in 1999 to 12% in 2002, but there is a long way to go to the tourist attraction that it was previously.

**Bleaching from 1999-2004:** Minor bleaching episodes were observed in 2003 and 2004 during periods of warmer weather in the Maldives, Bangladesh, and the Gulf of Mannar. Some islands around India had 10-20% of corals totally bleached and a similar percentage suffered partial mortality although recovery occurred within months. Sri Lanka's reefs showed minor bleaching episodes with minimal mortality.

### Southeast Asia

**Bleaching in 1998:** Moderate to severe damage was reported on Indonesia's coral reefs after the 1998 bleaching event and recovery has been variable. Reefs in the Philippines, Thailand, and Vietnam suffered widespread bleaching episodes leading to high, variable mortality. Recovery is occurring, yet will take time due to continued anthropogenic threats causing further stress.

**Bleaching from 1999-2004:** There is evidence of coral recovery in Cambodia, Indonesia, Philippines, Thailand and Vietnam after extensive coral bleaching mortality, mostly in the northern parts of Southeast Asia. In Indonesia, recovery has been slow in Sumatra and Lombok, but rapid in the Seribu Islands adjacent to Jakarta where coral cover is 40% on some reefs. Coral

## WHAT EFFECT WOULD DOUBLING ATMOSPHERIC CO<sub>2</sub> HAVE ON CORALS?

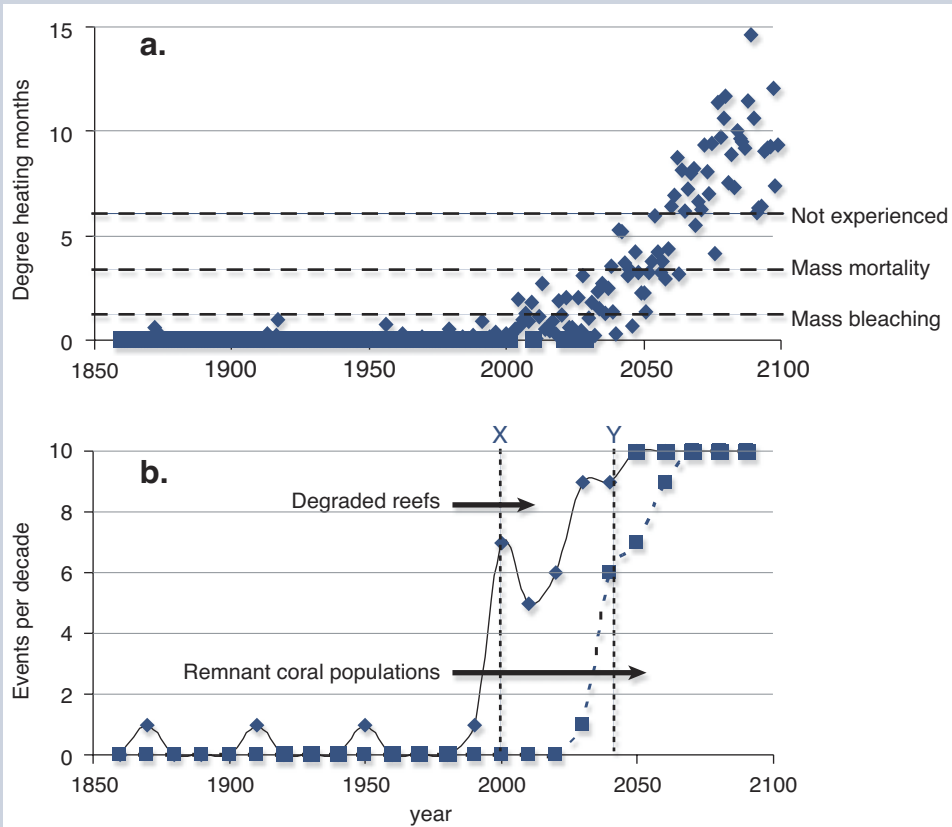
There have been at least 6 global mass coral bleaching events since 1979, with the most damaging being in 1998. These events were triggered by unusually warm conditions and water temperatures and have severely damaged many coral reefs around the world. The past damaging events have been analysed with satellite images by the National Oceanic and Atmospheric Administration (NOAA of USA) to produce 'degree heating weeks or months' anomalies in sea surface temperatures to predict potential future events. Degree heating months considers the size of the upward anomaly and the time that coral reefs were exposed, combined with direct observations of coral bleaching. When combined with projections of how sea temperature will change in tropical regions, the predictions are alarming with expected increases in frequency and severity of coral bleaching and mortality events.

Changes to the heat tolerance of corals may occur through acclimation or adaptation (Box p 25); however, there is no convincing evidence of large scale changes to the thermal tolerance of corals and their symbiotic algae. Changes to the composition of the symbiont populations inside corals (a form of acclimation) will provide some improved thermal tolerance to some corals. However, as with acclimation in all other organisms, there are limits to the role that this mechanism can play in coping with climate change. With changes in ocean temperature set to exceed the mild scenario (relative to other IPCC 2001 scenarios) presented here, reef scientists and resource managers must consider additional management options to account for some of the disturbing future scenarios in these analyses (from Ove Hoegh-Guldberg, oveh@uq.edu.au).

recruitment is low in the Gulf of Thailand indicating that recovery from the 1998 bleaching will be delayed. The coral reefs in the World Heritage Tubbataha reefs south of Palawan are showing rapid recovery after years of blast fishing and the 1998 bleaching event. Coral reefs in Bali show minimal bleaching and many corals are in excellent condition except for physical damage caused by dynamite explosions and localised anchor damage. In Tulamben and Seraya corals show little sign of bleaching.

### **East and North Asia**

**Bleaching in 1998:** Recovery in southern Japan from 1998 continues to be rapid. Coral mortality in the Ryuku and Yaeyama Islands were 30 to 90% with losses of large areas of *Acropora*. Although these are returning, there were some losses from bleaching in 2001. Shiraho Reef (Ryukyu Islands, Japan) survived the 1998 bleaching and is recovering at an unexpectedly fast rate. However, similar rapid recovery has not been observed on other reefs of the Ryukyu Islands. Much of the recovery is from asexual growth and fragmentation of larger colonies. There has been reasonable recovery on Taiwan after extensive coral bleaching in 1998, when 20% of coral colonies died on Penghu Islands, Lutaou, and Lanyu.



The figures show the effect of applying thermal thresholds derived from the last 10 years for bleaching of corals on the central Great Barrier Reef. The thermal threshold for most corals is around 28°C. The predicted changes to sea temperature with a doubling of CO<sub>2</sub> in the atmosphere were calculated using the best available global circulation models. The top part (a) shows how accumulated heat stress (as degree heating months) rises steadily over this century; bleaching events per decade over the next century (>1.0, dotted line) and severe events (>3.2, second dotted line) are drawn on the top part (a). More threateningly, the calculated values eventually rise above any value seen on reefs so far (> 6.0 upper dotted line). The lower diagram (b) projects outcomes for coral reefs as a result of the changes to thermal stress and reasonable mean responses by reef corals. Coral reefs that experience bleaching events every 2 years would degrade significantly; the dotted line X indicates when this point will be reached. When severe mortality events (when degree heating months >3.2) are experienced every 2 years, coral reefs are expected to be severely depleted as mortality will grossly exceed recovery rates; dotted line Y.

**Bleaching from 1999-2004:** The corals on Ishigaki Island, Japan may be showing potential acclimation to thermal stress, and were observed to survive in a bleached state for 6 months. Species richness has decreased at all sites because of 1998 and subsequent bleaching, with marked decrease of the former dominant species of *Acropora* (from Hajime Kayanne, Saki Harii, Yoichi Ide, and Fujio Akimoto).



## BLEACHING IN REEF-DWELLING FORAMINIFERA: A 20 YEAR RETROSPECTIVE

Reef-dwelling larger foraminifera share key characteristics with reef-building corals: both groups are prolific producers of calcium carbonate, both groups are physiologically dependent upon algal endosymbionts, and representatives of both groups have suffered bleaching episodes in recent decades. Bleaching symptoms were first observed in foraminifera in the early 1980s in laboratory experiments aimed at determining optimal culture conditions for the most common Caribbean and Indo-Pacific larger species, *Amphistegina gibbosa* and *A. lessonii*. Bleaching was first noted in field specimens collected in the Bahamas in 1988 during a coral post-bleaching survey. Since 1991, bleaching has been observed in populations of *Amphistegina* in all subtropical oceans, with peak bleaching in 1991, 1992 and 1998. *Amphistegina* populations exhibiting chronic, intermediate-intensity bleaching characteristically also show anomalously high incidences of shell breakage, shell deformities, and attack by predators and microorganisms, as well as damage to asexual reproduction and changes in population structure. A key difference between bleaching in corals and foraminifers is that coral bleaching correlates most consistently with elevated sea surface temperatures, while bleaching in *Amphistegina* is associated with photic stress. Throughout the 1990s, the incidences of bleaching in Florida Keys populations of *A. gibbosa* increased through the spring and peaked near the summer solstice, preceding late summer temperature maxima. Photic stress in laboratory cultures induced visible bleaching that was cytologically indistinguishable from bleaching in specimens freshly collected from the field. Increasing radiant energy by 20% above established optimal laboratory conditions by changing fluorescent light sources from “white” to “blue” induced chronic bleaching, without affecting rates of shell increase. Thus, while corals that are susceptible to bleaching apparently live near their upper thermal thresholds, *Amphistegina* thrive near their photic thresholds and are particularly sensitive to shorter wavelengths of solar radiation. Recognizing the similarities and differences between these taxonomically very different symbiotic systems may facilitate understanding the global decline of coral reefs (from Pamela Hallock Muller, pmuller@seas.marine.usf.edu).

### Australia and PNG

**Bleaching in 1998:** The reefs of the Great Barrier Reef have shown substantial recovery after the 1998 bleaching, assisted by the large scale of these reefs and the ready availability of coral larvae on reefs upstream. Some reefs that were severely bleached in 1998 still show dead standing corals, but most have healthy populations of new coral recruits. There has also been considerable recovery of reefs in the northern and central sections of the GBR after major losses of corals from the coral predator, the crown-of-thorns starfish. Similarly there has been substantial recovery on reefs damaged in 1998 off the Western Australian coastline. There is insufficient data to assess either the extent of coral bleaching or recovery in PNG, however the few data presented in Chapter 9 do indicate that there are concerns about coral bleaching damage to these reefs.

**Bleaching from 1999-2004:** There was significant coral bleaching along the length of the Great Barrier Reef (GBR) in 1998, with fringing inshore reefs in the Central GBR the worst affected;



but it was variable. Between 11% and 83% of colonies were bleached with 1% to 16% mortality, but also variable in species affected. By March 2004, many of the catastrophic declines in some species have been fully reversed, but others remain rare. Coral that reproduce by spawning have many new recruits, whereas those that brood larvae, are still rare. Thus the damage of the 1998 event is still evident in the coral communities, but total coral cover is returning to pre-1998 levels, illustrating the resilience of the GBR to impacts (from Andrew Baird and Paul Marshall). No bleaching occurred in Cobourg Marine Park, Northern Territory, in 2003 and 2004 (from victor.gomelyuk@plmbay.pwcnt.nt.gov.au). Minimal bleaching occurred in 2002 and no major damage was reported due to relatively quick recovery.

### Southwest Pacific

**Bleaching in 1998:** Coral bleaching and mortality was not a significant problem during the major global bleaching event in 1998 but there have been several bleaching episodes since then, particularly in Fiji, Tuvalu, and Vanuatu.

**Bleaching from 1999-2004:** In Taveuni (Somosomo Straits), there has been no recent bleaching and recovery from 2000 bleaching is variable but clearly evident, with many non symbiotic corals in high abundance. In Bligh Water, the pillar reefs are in excellent condition, and there is vigorous recovery of dead areas from earlier bleaching, including patches of table and branching *Acropora*. In Lomaiviti, there is regeneration of hard corals everywhere, including much vigorous growth. Kadavu (south Great Astrolabe Reef, Madava to Ono) has some high coral cover, but generally very low coverage and sparse regeneration. (from Les Kaufman, lesk@bu.edu).

There was an average of 70% bleaching of the *Acropora* corals in Funafuti Lagoon, Tuvalu in 2000, when water temperatures were 30.5°C to 32°C. But there was less than 10% for the Agariciidae, Faviidae and Mussidae (from Samasoni Sauni, sauni\_s@usp.ac.fj and Ron Vave).

Hard and soft corals on some Fijian reefs began bleaching in early 2000 and by mid-July most colonies were either recovering or dead and being colonized by algae. Some Savusavu reefs experienced 60 to 80 % hard and soft coral mortality down to a depth of 10 m with Acroporids most affected. Reefs with lower coral diversity and abundance seemed to suffer less than those with increased cover and diversity yet the bleaching and resultant mortality was quite variable, with the highest mortality along the southern portion of Viti Levu and Vanua Levu. Inshore reefs showed greater survivorship and these large areas of healthy coral, as well as deeper reefs, which were less affected should bode well for a large recruitment to the areas of high mortality (from Richard Murphy, Rmurphy000@aol.com and Ed Lovell, lovell@suva.is.com.fj).

The Mamanucas Islands of Fiji are continuing to recover from the 2000 bleaching event and show an increase in total hard coral cover and a decrease in dead coral and macroalgae cover between 2001 and 2003, suggesting that the reef habitat is generally in a good condition. However, assessments of new sites in 2003 suggest that tourist development may have impacted shallow reef habitats around some of the smaller islands within the archipelago. The presence of dense beds of the macroalgae *Gracilaria* may be related to elevated nutrient levels in nearshore waters yet the potential causes of these extensive macroalgal beds are unknown (from Ryan Walker, rw@coralcay.org).

### **Polynesia Mana -Southeast Pacific**

**Bleaching in 1998:** There were no large impacts throughout Polynesia from bleaching in 1998, however there was severe bleaching on some parts of reefs e.g. coral mortality was over 90% on some outer reef slopes in Rangiroa. These reefs have shown rapid recovery, although there has been some repeat bleaching.

**Bleaching from 1999-2004:** Bleaching events in Polynesia Mana have been more frequent and severe during recent times. Approximately 80% of *Acropora* bleached in 2000 in the Cook Islands and up to 90% of *Platygyra* and *Goniastrea* bleached in Tonga. The Society Islands in French Polynesia suffered bleaching in 2001 along many barrier reefs and lagoons, and general bleaching along the outer reef slopes persisted for several months, with about 10% mortality.

### **Micronesia**

**Bleaching in 1998:** Some of the most extensive bleaching and subsequent coral reef damage was seen in Palau in 1998. Some reefs have coral cover in the range of 50 - 70% suggesting that they escaped the major impacts of the 1998 bleaching, or recovered soon after. There are, however, reefs with 10 - 25% coral cover and with large amounts of dead standing coral indicating that these reefs were badly affected. There were reports from Palau immediately after the 1998 bleaching of up to 50% mortality on some reefs. *Acropora* corals were virtually wiped out on some offshore reefs, whereas reefs in more sheltered lagoon waters showed lower rates of loss. New coral recruitment has been very encouraging, including many of the *Acropora* species which were severely affected in 1998, however the major concern is that there are large numbers of crown-of-thorns starfish feeding on the newly settled colonies. The other countries of the Micronesian Node were not seriously affected in 1998.

**Bleaching from 1999-2004:** Bleaching was restricted to most shallow water *Acropora* in the Republic of the Marshall Islands during 2000. More shallow bleaching was reported on Jaluit, Mili, Arno, and Likiep in 2002 with complete mortality of many *Acropora* dominated coral reefs particularly along inshore regions such as reef flats. Deeper episodes occurred in 2003, with partial bleaching of giant *Porites* colonies, *Millipora*, *Lobophyllia* and other species showing substantial recovery. Shallow lagoons dominated by *Acropora* colonies showed signs of mortality alongside scattered bleaching of *Pocillopora* colonies. A visit to Jaluit atoll in early 2004 revealed that bleaching still persisted in many large tabulate/branching *Acropora* colonies: bleaching was restricted to well lit surfaces and was absent in shaded areas. Lagoon mortality was detected in the shallows (< 3 meters) (from Dean Jacobson, atolldino@yahoo.com).

### **Hawaiian Archipelago**

**Bleaching in 1998:** The 1998 bleaching event was not significant for Hawaii's coral reefs. In fact, there were colder than normal sea temperatures while the other side of the Pacific was abnormally warm.

**Bleaching from 1999-2004:** The first mass coral bleaching ever recorded in the remote Northwestern Hawaiian Islands (NWHI), a chain of small islands, atolls, and banks that span ~1800 kilometres in the northwest portion of the Hawaiian Archipelago, was documented in late summer 2002. Towed-diver surveys covering more than 195 km of benthic habitat and belt-transect surveys at 118 sites were conducted at 10 reef systems throughout the NWHI to assess coral bleaching across latitude, depth, zone, and taxon. The incidence of bleaching was greatest at the 3 highest-latitude atolls in the Hawaiian Archipelago (Pearl and Hermes, Midway, and

## MARINE TURTLES NEED CORAL REEFS AND VICE VERSA

Marine turtles across the globe are endangered or critically endangered following continued and unrelenting anthropogenic stress: they are harvested for their meat and oils, shells are taken for curio-making, eggs are taken for food, and a number of body parts are considered potent aphrodisiacs. Millions of hawksbill turtles were killed during the 20<sup>th</sup> century to supply worldwide demand for tortoise shell. In the late 1970s at least 46 countries exported raw shell to numerous importing countries. Although now protected by laws in nearly every range country, loopholes and unscrupulous exploitation fuel a level of exploitation far in excess of that which can be supported by most populations, although some show clear signs of rebound and recovery, such as some Caribbean species. Hawksbills in this region inhabit inshore reef ecosystems and the majority of the population is within the national waters of many different countries at any time, making their conservation a shared concern. There have been reductions in excess of 80 % at many important breeding sites throughout the world. Nicaragua, Panama, Madagascar, Sri Lanka, Thailand, Malaysia, Indonesia, and the Philippines have shown turtle declines during the last 100 years. Currently, a handful of hawksbill populations are stable or increasing, but these are the exception rather than the rule, and involve populations that have been subject to long-term and effective protection for over a decade.

Coral reefs are well known for harbouring the critically endangered hawksbill turtle *Eretmochelys imbricata* which relies on sponges living among corals among its main diet components, making it one of the only organisms that has glass as a main component of its daily intake. The glass spicules in sponges serve to deter a major portion of underwater predators, but once the soft tissues are opened up by turtles many sponges are prey for less robust feeders. Turtles play an integral role in the maintenance of underwater life cycles, and a decline in turtles will likely result in an overpopulation of sponges, taking up valuable reef space and not contributing to reef-building in the way calcareous corals do. Turtles additionally provide a tourist attraction and the link between turtles, conservation funding and habitat protection cannot be overemphasised. The successful conservation of hawksbill and other turtles, such as the green turtle *Chelonia mydas*, is inextricably linked to the protection and maintenance of their habitats. No habitat, no turtles, it's that simple (from Nicolas Pilcher, pilcher@tm.net.my, and Roderic Mast r.mast@conservation.org).

Kure), with lesser incidences of bleaching on reefs at Lisianski and farther south in the NWHI. At the 3 northern atolls, bleaching was most severe on the back-reef, moderate in the lagoon, and low on the deeper fore-reef. The average incidence of coral bleaching experienced closely corresponds to the composition of the dominant coral fauna coupled with its susceptibility to bleaching. Prolonged, elevated sea surface temperatures are a likely explanation for the bleaching response.

In 2004, thermal stress began to develop in the Northwestern Hawaiian Islands beginning in mid-August and increased through early-September. Recent surveys have confirmed substantial coral bleaching among *Montipora patula*, *Porites evermanni*, and *Porites lobata*

at Maro Reef, Laysan, and Lisianski. The shallow backreef habitats of Pearl and Hermes Atoll and Midway Atoll were also significantly bleached while Kure, the northernmost atoll in the Hawaiian Archipelago, showed similar yet less pronounced bleaching. (from Jean Kenyon, Jean.Kenyon@noaa.gov).

### **US Caribbean and Gulf of Mexico**

**Bleaching in 1998:** In 1998 there was extensive and intensive bleaching affecting the majority of coral reefs around Puerto Rico and the US Caribbean. In the southwest region and Mona Island, a large number of coral colonies, hydrocorals, octocorals, and zoanthids bleached completely (100% of living surface area) down to 40 m deep. Maximum temperatures measured during 1998 in several reef localities ranged from 30.15°C (20 m deep) to 31.78°C at the surface. Of the 386 totally bleached colonies tagged and monitored for over a year after the event, many colonies of corals and zoanthids remained bleached for over 120 days, even after water temperatures dropped to 25-26.5°C in winter. While most of these colonies regained their normal coloration by December 1998, some showed bleached tissue until 1999 before they recovered their coloration (zooxanthellae). Mortality rates were minimal (< 0.1%) with some colonies (< 5%) showing increased partial mortality.

**Bleaching from 1999-2004:** Bleaching occurred in 1999 yet was less intense than the 1998 episode; a significantly lower number of colonies were affected and no colonies fully bleached. Between 6 and 13% of all corals and between 12 and 31% of the hydrocorals showed bleaching symptoms (from pale to white areas over the colony) and a further 15% bleached in 1998 and 1999. No coral or hydrocoral mortality was observed this year and 99% of all bleached colonies regained their normal coloration by the end of the year. Minimal bleaching was observed in many reef localities including Bonaire, parts of the Caribbean and Bermuda in mid-1999.

No significant bleaching occurred from 1999 through 2002, but the 2003 bleaching event was an intense event producing complete mortality of many colonies (mostly hydrocorals (*Millepora complanata* and *M. alcicornis*, the colonial zoanthid *Palythoa caribaeorum* and the crustose octocoral *Erythropodium caribaeorum*). Some shallow areas (< 10 m) dominated by these organisms appeared white for over a month. The 2003 bleaching event was more intensive and extensive in shallow water reef habitats (< 10 m) compared to the 1998 event, which started in the deep areas of the reefs (> 15 m) before affecting the shallow habitats. Coral colonies on the other hand, showed a highly variable pattern of coloration loss, from white and pale blotches irregularly distributed over the colony surface to uniformly paling all over the colony. It was significantly less intensive (with very few colonies bleaching totally) in deeper waters this time around. This pattern was different from that of 1998, when a high proportion of colonies went completely white all over the depth gradient of the reefs, from shallow to deep reef habitats. The 2003 event also affected a wider range of taxa compared with the 1998 event. These included scleractinian corals, octocorals, hydrocorals, other hydrozoans, anemones, zoanthids, and even some sponges. Shallow, near-to-shore reefs were more affected (an average of 20.2% of all coral colonies bleached) than mid-shelf fringing reefs (13% of all coral colonies bleached), and deep, offshore (> 7 km from coast) bank reefs at the edge of the insular platform (7.3% of all colonies bleached). This same trend was observed for hydrocorals with an average 36.5% colonies bleached in near shore shallow reefs compared with 26.7% and 27.0% for mid-shelf fringing reefs and deep offshore bank reefs, octocorals (5.5% and 5% of bleached colonies in near-shore and mid-shelf reefs compared with 1.1% bleached colonies in deep bank reefs) and zoanthids (37.3% in near shore reefs 31.8% in mid-shelf reefs and 1.85%

of colonies bleached in deep bank reefs). Of the 386 colonies tagged in 1998, 17 have been affected by diseases in the last years. Only 2% of the deep-water colonies bleached all the way to a white patterns, 155 were pale and the rest showed no signs of bleaching. Only 5% of shallow water colonies showed intensive bleaching pattern (white blotches and extensive paling areas), however, the great majority (95%) of the tagged colonies (mostly *Montastraea faveolata* and *M. annularis*, *Colpophyllia natans*, *Acropora palmata*, *Siderastrea siderea*, *Stephanocoenia intersepta*, *Diploria strigosa* and *D. labyrinthiformis*) were slightly pale all over or showed few pale areas over the colony compared to other nearby colonies that did not bleached in 1998. Overall the event lasted a short period of time compared to the 1998. This is probably related to the late onset of the event and the drop in water temperature soon after it started (from Ernesto Weil, eweil@caribe.net).

In early November 2003, pale corals were observed along the south coast of Jamaica, including the Portland Bight area. Rackham's Cay and Drunkenman's Cay displayed widespread bleaching in shallow (3-5 m) water (*M. annularis* appeared worst affected along with *M. faveolata*, *Colpophyllia natans*, *Porites porites* and the zoanthid *Palythoa caribaeorum*). Additional species seen to be bleached at Portland Bight included the gorgonians *Erythropodium caribaeorum* and *Plexaurella* sp. In early 2004, bleaching at Rackhams Cay was still widespread, but corals appeared to be recovering. Some *M. annularis* colonies had small dead patches, probably resulting from the severe bleaching. By April, bleaching had almost completely gone, but there were many small dead patches on some coral heads. Hot-spot maps confirmed the presence of abnormally warm water at the south coast of Jamaica during October 2003. This period was also notable as having been unusually calm, clear water (from George Warner, george.warner@uwimona.edu.jm).

There was no large scale bleaching observed in Florida during 2004 but minor and moderate evidence of bleaching was seen in the lower Florida Keys and Tortugas areas, mostly of *Millepora complanata*. The hurricanes which struck Florida this year, possibly decreased the chances for coral bleaching by cooling the water via cloud cover and heavy rain fall. However, quantitative data from the resultant physical damage caused by the hurricanes high winds and storm surge are still being acquired and processed (from Walt Jaap, Walt.Jaap@MyFWC.com). In St. Croix, US Virgin Islands, variable bleaching was noted across a variety of depths (0-25 m) in 2002-2004 with some sites containing no bleached colonies while others had up to 30% of colonies showing bleaching symptoms. Similar surveys at St.Thomas, US Virgin Islands in 2003 and 2004 found more severe bleaching with some corals bleaching at over 40 m depth (from Steve Herzlieb, sherzli@uvi.edu).

### Mesoamerica

**Bleaching in 1998:** The coral reefs from the Yucatan, Mexico to Honduras suffered severe damage from two major disturbances in 1998. First there was severe coral bleaching which was followed soon after by the major hurricane 'Mitch'. This double impact destroyed many corals with some losses up to 75% in Belize. Overall there has been a 50% reduction in live coral cover in Belize between 1997 and 1999, and cover has remained relatively stable at that level with slow recovery in progress.

**Bleaching from 1999-2004:** In June and August 2004 at several sites in Belize, there was bleaching of *Acropora* but not other species. This bleaching was to low numbers of *Acropora* in Glovers following Hurricane Mitch in 1998 and other bleaching events (from Brie Cokos, bcokos@rsmas.miami.edu).



### Eastern Caribbean

**Bleaching in 1998:** Like other parts of the wider Caribbean region, there was moderate to severe coral bleaching in 1998, but generally there were low levels of mortality. At one site on Barbados, approximately 20% of bleached corals did not survive, but there were complicating pollution factors. Most reefs are showing signs of recovery from hurricanes, and sediment and bleaching damage from the previous 10 years.

**Bleaching from 1999-2004:** There has been regrowth of *Acropora palmata* and *A. cervicornis* in small patches on the reefs where they had been completely killed in the 1998 event on San Salvador, Bahamas. These are growing quickly, although some have white band disease Type II that infected the original colonies at the time of the bleaching. The regrowth is a mix of recovery of old colonies but mostly new recruits. The bleaching event in 1998 killed all the *Acropora cervicornis* most of the *A. palmata* on their monitoring transects, along with about 20% of the *Montastraea* spp. The monitoring shows no regrowth of *A. cervicornis* on the transects, but it is growing elsewhere, illustrating the need for broader surveys at the same time (from Tom McGrath, mcgratta@corning-cc.edu).

### Southern Tropical America

**Bleaching in 1998:** Bleaching appears to have increased in frequency, but not in severity throughout the 1990s. Mild bleaching occurred throughout the region in 1998 although coral mortality was insignificant.

**Bleaching from 1999-2004:** There was predominantly slight coral bleaching during the major 1997-98 El Niño throughout the region and minimal mortality. The exception was in the North Bahia and the Abrolhos region, Brazil where there was up to 80% of corals bleached, but nearly all the corals recovered after 6 months. The major damage to these reefs from bleaching occurred in the 1980s and early 90s. Recovery is slow as the reefs are under a wide range of anthropogenic pressures.

### CORAL AND OTHER DISEASES

There has been a worldwide increase in reports of diseases of marine organisms including fish, sea urchins, shellfish, sponges, marine mammals, and especially corals. Since the 1990s, coral diseases have increased in number, affected species, and geographic range, with diseases affecting over 150 species from the Caribbean and Indo-Pacific alone. The rate of discovery of new diseases has also increased considerably, with more than 29 coral diseases now described. Coral diseases can potentially produce severe population declines, threaten biodiversity, and shift the structure of reef communities by challenging the resilience of these systems. This has been emphasised in the wider Caribbean when several outbreaks of coral diseases resulted in massive losses in corals, particularly the dominant reef builders the *Acropora* species in 1970s and 90s.

Although coral disease is emerging as a major threat to Caribbean coral reef health, we currently know very little about the ecology or pathology of coral disease on Indo-Pacific reefs, despite the region encompassing more than 80% of reefs worldwide. The relatively few reports of coral disease from Indo-Pacific reefs suggest that either disease is genuinely more prevalent in the Caribbean or a lack of research in other regions is underestimating influence and severity. The rising incidence of marine diseases worldwide in the past few decades emphasises the need for increased assessment of the status of disease in order to identify the origins and reservoirs of pathogens and the vectors involved in disease transmission (from Bette Willis, bette.willis@jcu.edu.au).

Stress appears to lower a coral's resistance to disease and thus affects its ability to survive. Because elevated temperature is a coral stress, increasing predictions of global climate change (Box p 72) may also result in increasing incidence of coral disease. It is possible that proximity to human population centres may increase the likelihood of infection. Disease outbreaks are nearly impossible to manage because the connectivity of the marine environment increases the speed of disease transmission and renders standard response such as quarantine and vaccines ineffective. Preventing nutrient runoff into coastal areas by managing water quality could be an important measure and the relationship between increased nutrients and disease severity should be viewed as a top priority for ecologists and resource managers.

Now that there are many reports of diseases found in coral reefs around the world, 2 questions need to be asked: Are there now more reports of disease because more people are looking for such incidences and are there actually more incidences of disease in many parts of the coral reef world? The answer to these questions is probably yes as the reports below indicate.

### **Coral Disease in the Indian Ocean**

There has been a worldwide increase in the reports of diseases affecting marine organisms however our ability to fully understand recent disease outbreaks is hampered by the paucity of baseline and epidemiological information on the normal disease levels in the ocean. The Indo-Pacific region has a much greater species richness than the Caribbean yet the number of species affected by disease is proportionally much lower. The coral reefs of the wider Caribbean have experienced major levels of disease to corals and other organisms for many decades, whereas there have been few reports of coral disease in the Indo-Pacific region – until recently. New research, combined with recent surveys and observations, indicates that infectious pathogens may be a common component of Indo-Pacific reef communities and may have a greater role in structuring coral communities in the region than previously thought.

Surveys in the Central Visayas and Lingayen Gulf, Philippines showed that 8.3% of coral colonies were affected by 1 of 3 diseases on *Porites* species: *Porites* Ulcerative White Spot Disease; an undescribed neoplasia; and 'Pigmentation Response' (previously 'Pink Line Disease'). The long-term consequences are not known but *Porites* are major reef builders on Indo-Pacific reefs. No signs of the previously recorded Black Band Disease and White Band Disease were observed (from Laurie Raymundo, lraymundo@guam.uog.edu).

The first incidence of Yellow-Band Disease in the northern Persian Gulf was observed around Farur Island in 2000 at a moderate level (<5%) in depths from 6 to 12 m. This disease has been previously reported from the Southern Persian Gulf and Gulf of Oman (from Mohammad Reza Shokri Bousjein, mohammad.shokri@studentmail.newcastle.edu.au).

Although rapid surveys of a number of diseases identify general trends, more detailed surveys are needed to accurately estimate the impact of disease on coral populations. A key objective will be to determine rates of mortality caused by disease and to put them into context with mortality caused by other disturbance agents on Indo-Pacific reefs, such as bleaching events, cyclones and *Acanthaster planci* outbreaks. It will be equally important to determine rates of disease spread and tissue loss within colonies and their associated impacts on colony fecundity and growth, to fully understand the impact of diseases on coral populations.



### ISRS STATEMENT ON DISEASES ON CORAL REEFS

Diseases of corals and other organisms have caused significant damage to the structure and appearance of coral reefs, at similar scales to coral bleaching and plagues of the crown-of-thorns starfish. Marine diseases are natural processes, but have been poorly studied because they are often ephemeral and rarely observed until much too late. The International Society for Reef Studies and a group of experts compiled a consensus statement of current knowledge. They concluded that disease epidemics pose serious threats to the health of coral reefs worldwide and that human activity is at least partially responsible for recent disease outbreaks following the identification of many of the responsible pathogens. Two diseases have had major impacts on Caribbean reefs: in 1983-84 a disease (possibly arriving in ship ballast water near the Panama Canal) was carried by currents throughout the Caribbean killing more than 95% of the long-spined sea urchin, *Diadema antillarum* and White-band disease inflicted enormous losses on the major reef builders, the staghorn and elkhorn corals (*Acropora cervicornis* and *Acropora palmata*) throughout the Caribbean in the 1980s and 1990s. The effects still remain and the urchin populations have not recovered. There is no evidence of similar diseases in the fossil record for several thousand years on recently devastated reefs.

Ecological studies on coral reefs suggest that the incidence of disease has risen recently. However, there is very little historical information and this conclusion cannot be confirmed as real or a reflection of more research activity. There are 4 to 6 confirmed coral diseases in the Caribbean, possibly up to 15, with bacteria, fungi, and cyanobacteria ('blue-green algae') the known causal agents. A fungal disease of gorgonians (sea fans) probably came with sediment runoff from the land as a result of human activity. This is one example why marine scientists suspect that human stresses, such as pollution and changing patterns of land use, have promoted the spread of white-band disease in Florida and the Caribbean. Stress may compromise disease resistance, allowing infections to take hold and new diseases to emerge. Reliable information states that black-band disease and 'plague type II' are caused either by a single bacterium or a consortium of bacteria (including cyanobacteria) and these attack mostly the massive brain and star corals. Now diseases are killing corals on Pacific, Indian, and Atlantic Ocean reefs. It is probable that stressed and bleached corals because of high sea temperatures are more susceptible to disease. For example, black-band disease and white-band disease have now been identified throughout the tropical Indo-Pacific, including the Red Sea, Mauritius, the Philippines, Papua New Guinea, and the Great Barrier Reef of Australia. The newly discovered yellow-band disease is affecting up to 75 percent of the coral colonies in parts of the Arabian/Persian Gulf. The rate of reef construction will be less if corals are affected by disease and reduce their capacity to act as shoreline protectors and keep up with sea-level rise. Damaged reefs will also provide fewer resources, especially fish and other seafood. Improved studies of coral diseases and associated impacts are required to assist in the management reduce threats to coral reefs. The full text is available at: [www.fit.edu/isrs/council/disease.htm](http://www.fit.edu/isrs/council/disease.htm).

### Coral disease in the Pacific Ocean

Recently, significant attention has been paid to the study of coral disease in the Pacific Ocean, resulting in emerging information on the identification, characterization and distribution of diseases. As more studies are conducted on Pacific reefs, a clearer picture of what diseases exist and the mechanisms of dispersal across the Pacific should develop. Future work should seek to compare types, distribution and prevalence of coral disease in the Pacific Ocean with coral reefs from other ocean regions.

Coral populations in the Hawaiian Archipelago continue to be spared from epidemic disease outbreaks unlike many other corals reefs around the world. Surveys at 18 sites around Oahu show an average prevalence of disease (# diseased colonies/total # colonies) at less than 1% although differences in disease prevalence were found between coral genera. *Porites* sp. had the highest prevalence of disease and the most common was growth anomalies or 'tumours'. Similar anomalies have not been documented in the Northwestern Hawaiian Islands (NWHI) despite extensive coral disease surveys. The cause of *Porites* tumours is unknown but the occurrence of tumours is positively correlated with colony size (a broadly generalized proxy for colony age).

Another common disease found in the main and NWHI is *Porites* trematodiasis, caused by the larval stage of the digenetic trematode *Podocotyloides stenometra* and characterised by pink, swollen nodules. The greatest abundance of infected coral has been found on the reefs in Kaneohe Bay on the windward side of Oahu where infected corals have been found in all reef zones and have persisted on the reefs since the 1970s. Trematode infection can cause reductions in coral growth of up to 50%. General coral necroses also commonly occur on Hawaiian reefs and can follow only three outcomes:

- complete recovery;
- successional change from turf to crustose coralline algae on which new coral recruits become established; or
- persistence of the turf community with a net loss of coral cover.

The Northwestern Hawaiian Islands are considered to be one of the last relatively pristine large coral reef ecosystems remaining in the world. There has been historically little research done to capitalise on the unique opportunity to document normal disease levels in a coral reef system exposed to limited human influence.

During a multi-agency research survey conducted in 2002, disease investigation was incorporated into the protocol and a characterization of coral disease was initiated. In July 2003, surveys were conducted at 73 sites throughout the NWHI to quantify and characterise coral disease occurrence. Low levels of coral disease was found at 68.5% of the sites throughout all regions and the most common disease was *Porites* trematodiasis which was found at 57.5% of the sites exclusively affecting *Porites* sp. Numerous other conditions were observed at much lower frequency of occurrence (1.4% - 16.4% of the sites). The overall average prevalence of disease was approximately 0.5% (range 0-7.1%) yet a disease outbreak at one site at French Frigate Shoals resulted in massive tissue loss on large acroporid table corals. Differences in types of conditions and prevalence of disease were found among coral genera. Pocilloporids, which are one of the most common types of corals found on the reefs of the NWHI, appear comparatively resistant to disease as only a single diseased colony found out of over 6000 colonies that were

searched (prevalence=0.016%). In contrast, acroporids make up less than 5% of the coral community yet showed the greatest damage due to disease and the highest prevalence of disease (prevalence=2.7%). Although no major die-off of corals has ever been documented due to disease in Hawai'i increasing human usage and the impacts of global climate change are raising concern about the health of Hawaiian reefs. Plans are currently underway to extend base-line disease surveys out to the other main Hawaiian Islands and the Hawaii State Division of Aquatic Resources will also be integrating coral disease assessment in their monitoring program.

In 2004, surveys were conducted at 12 sites at Johnston Atoll to quantify and characterise coral disease. Due to harsh weather conditions surveys were limited to sites within the lagoon. Signs of coral disease were evident at 92% of the sites surveyed. The average prevalence of disease (# diseased colonies/total # colonies) was estimated at 3.1%, which is higher than what has been reported for the Northwestern Hawaiian Islands (avg. estimated prevalence=0.5%). Types of diseases included growth anomalies on *Acropora* and *Montipora*, white syndrome on the table coral, *Acropora cytherea*, distinct patches of tissue loss on *Montipora patula* and *M. capitata* and Pacific Montiporid ring syndrome with affected corals having abnormal growths with many having tissue death in the centre producing a ring-like lesions. Similar disease signs during a qualitative assessment of coral disease in 2001 (from Greta Aeby, greta@hawaii.edu).

Until recently, it has been assumed that disease has had little impact on the population dynamics or community structure of coral assemblages on the Great Barrier Reef (GBR). However, the presence of a number of pathogens on the Great Barrier Reef that have had major impacts on other coral communities around the Caribbean such as black band disease and one or more of the diseases within the white syndrome category, emphasises the severity of the threat posed by predicted environmental changes. Surveys of disease prevalence on reefs representative of the major habitats and community types throughout the GBR are required in order to document the full range of pathogens and to establish a baseline to judge whether disease incidence is increasing.

Research is now also underway to document coral disease in Japan however there have been neither quantitative surveys for coral disease nor any studies examining disease outbreaks associated with water quality. The primary objective being to document the baseline levels of disease in the major genera of corals in Japanese waters.

Minimal signs of coral disease were found at 11 sites during surveys around Tutuila, American Samoa in 2004. The most common diseases were Acroporid White Syndrome (prevalence ranging from 0-1.1%), Acroporid growth anomalies (prevalence ranging from 0-5.3%), Montiporid White Syndrome (prevalence ranging from 0-1.9%) and Montiporid growth anomalies (prevalence ranging from 0-0.97%). Coralline Lethal Orange Disease was found at 45% of the sites and the number of infections ranged from 0-33 CLODS/site (From Greta Aeby, greta@hawaii.edu).

A fatal epizootic to tabulate *Acropora* (as well as some non-tabulate species such as *A. gemminifera*) is progressing along the south ocean shore of Majuro, Marshall Islands. The disease was quite common among the smallest *Acropora* sp. on the coral platform (4-6 m) on the far eastern end of Arno (south ocean shore). The disease is characterised by a white band ranging from mm to cm in width (depending on spread rate) sweeping across the colony, preferentially along the edge. Typical spreading at 2-6 cm/day the disease involves *Acropora* from 2 m to 15 m depth. Densities of actively diseased tables are typically 100-200/ km of coast

and as of mid 2004 densities of diseased killed corals are 1000-2000 colonies/km. The disease progression lasts approximately 20-30 days for small colonies, up to 9 months for a 2 m colony, sometimes spreading between adjacent colonies, but most affected colonies are solitary and seemingly randomly distributed, although disease clusters of 5 or more adjacent colonies are encountered. Highest incidence rates are at the west and east ends of Majuro. A low incidence of disease is found in sparsely-populated Woja and Kalalen pass along the northern margin of the atoll. Other notable diseases include the fatal “green band” disease infecting *Platygyra sinensis* and CLOD, which is found at Delap Point (from Dean Jacobson, atolldino@yahoo.com)

### **Coral Disease in the Atlantic Ocean**

For some reason, the Caribbean appears to have experienced a far higher incidence of disease to coral reef organisms than reefs of the Indo-Pacific (at least 82% of Caribbean coral species are susceptible to disease, compared to 25% of Indo-Pacific corals). Several hypotheses have emerged: the Caribbean is semi-enclosed such that the reefs are in relatively close contact due to the gyres of water; there are higher concentrations of nutrients and possibly pollutants because of these gyres that circulate large volumes of waters flowing in from major rivers e.g. Amazon and Mississippi; and the reefs have been isolated from the others for millions of years. The region also has a higher population of scientists regularly monitoring the reefs for problems. These remain fundamental questions for researchers to address in coming years.

In the 1930s, there was a major disease outbreak that devastated the sponge industry. This seems to have been repeated in the 1990s when commercial sponges to the west of Florida were virtually eliminated. But the most dramatic and devastating diseases have been to corals, gorgonians and to sea urchins.

Populations of the sea urchin, *Diadema antillarum* were virtually obliterated when a disease killed over 95% of them throughout the Caribbean during 1983-84. This emphasised a major difference between coral reefs in the Caribbean, where urchins are the major grazers on algae, and elsewhere where the major grazers are fishes. These urchins had been so prolific that the numbers reached as many as 6 per square metre – until they die off. The disease that killed these urchins probably originated near the Caribbean entrance to the Panama Canal and spread to the southeast and north from this point. The major impact on the reefs, however, was a massive explosion in fleshy algae causing many corals to be smothered. Thus this disease outbreak had far reaching consequences which are still evident in 2004; 20 years after the death of the urchins and the populations have only recovered to about 4% of their original status and the coral cover is still depleted.

Stress is often associated with increased susceptibility to disease and many studies have suggested a correlation between elevated sea temperatures, sedimentation, and pollution. Of the 18 coral diseases described to date, 4 are reported globally, 9 are found only in the Caribbean, and 6 appear to be found only in the Indo-Pacific. Increases in the number of new diseases and affected species may be linked directly to human-induced alterations in coral reef environments both in terms of land-based sources of pollution as well as global climate change issues such as global warming. Increasing ocean temperatures may play a significant role in coral disease as pathogen growth and virulence increases with temperature while at the same time coral immune response decreases. Nutrient and sediment loading may deliver disease organisms to the marine environment (from Jim Porter, jporter@uga.edu).

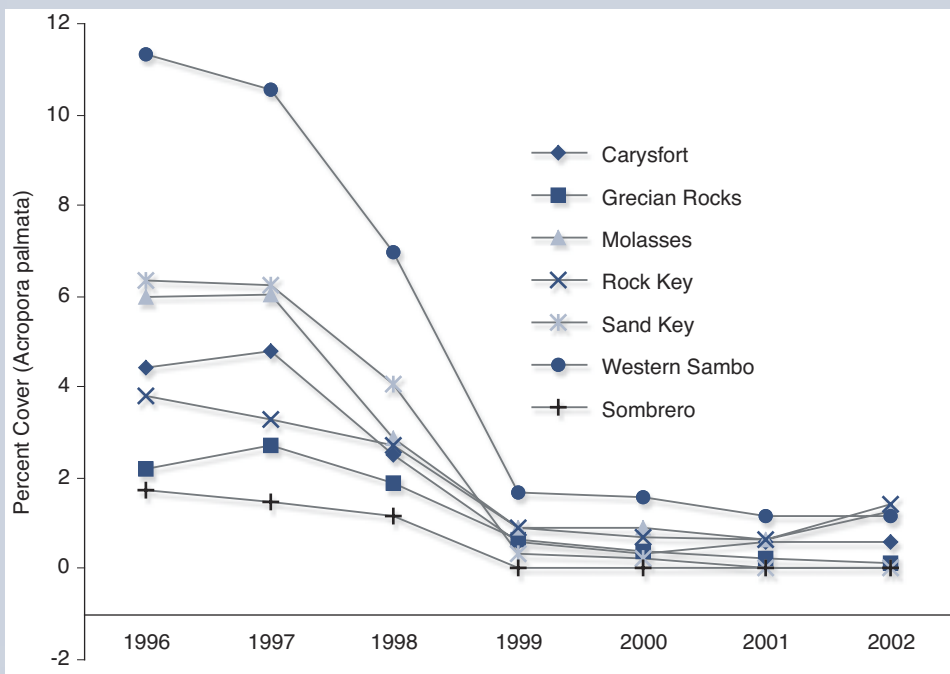
In the Caribbean, populations of elkhorn (*Acropora palmata*) and staghorn (*A. cervicornis*) corals are being devastated by disease. Within the Florida Keys National Marine Sanctuary from 1996-2004, the number of stations exhibiting disease increased 404% and the number of species exhibiting disease increased 218%. These increases correspond to a 37% decline in coral cover at the same stations during the same time.

Field experiments have shown that increased nutrient levels can significantly increase the severity of 2 important Caribbean diseases: aspergillosis of the common gorgonian sea fan and yellow band disease of some reef-building corals. Researchers hypothesize that the additional nutrients increase pathogen fitness and virulence, leading to increasing intensity and frequency of disease outbreaks. Nutrient enrichment can occur at many scales (metres to kilometres) and is influenced by human activities including agricultural runoff and increased reliance on fertilizers as well as many natural processes including upwelling and internal tidal bores. Researchers hypothesize that pristine reefs may eventually experience nutrient enrichment and mortality as a result of increasing human activities and development. Scientists have already observed a high prevalence of Dark Spot Syndrome on *Siderastrea siderea* at 5 “pristine” reefs near Lee Stocking Island, Exuma Cays, Bahamas. Reefs in Belize and Puerto Rico are showing similar patterns with 39% disease prevalence among *S. siderea* at Ambergris Cay on the northern part of the Belize barrier reef and 29% on the central barrier reef at Southwater Cay. In Puerto Rico, there is also a high prevalence of Dark Spot Syndrome prevalence with 46% at La Parguera, 65% at Aquadilla, 70% at Cabo Rojo, and 40% at Culebra (from Deb Gochfield). White plague disease has also been observed in the region along the islands of San Andres and Old Providence (Western Caribbean, Colombia). The incidence of disease has increased in both islands, but the species affected vary with brain corals (genera *Diploria* and *Colpophyllia*) seeming to be the most affected at San Andres and *Montastraea annularis* and *M. faveolata* most distressed in Old Providence. Approximately 20% of the coral cover has been killed by the disease at San Andres yet the extent of mortality in San Andres is around 10% (from Valeria Pizarro).

Disease is changing the composition, structure, and function of the Florida Keys coral reef ecosystems. In extensive surveys from Key Largo to Key West in 160 stations at 40 sites, there has been an enormous increase in the number of locations affected, the number of species affected, and the rate of coral mortality. The disease outbreaks are having community-wide effects as common corals are becoming rarer and rare corals may be becoming locally extinct. The future of certain coral reef sites may be in jeopardy as predictions of coral disease becoming more common and more widespread over the next quarter century become increasingly more believable. It is uncertain whether these diseases are the expression of an episodic pathogen with short term ramifications or a widespread pandemic with long-term ramifications. Research and monitoring is absolutely critical to discern which of these alternative ecosystem-wide processes is at work (from Jim Porter, jporter@uga.edu).

## WHITE POX DISEASE RAVAGES CARIBBEAN CORAL

Within the Caribbean, populations of the once most common reef-building coral, *Acropora palmata*, are being decimated, with losses of living cover in the Florida Keys averaging 87%. Severe population declines of *A. palmata* in Florida and elsewhere in the Caribbean have led to the identification of this species as a candidate for protection under the Endangered Species Act (Box p 15). The majority of recent losses of elkhorn coral in the Florida Keys are associated with white pox disease. The disease was first documented in 1996 on reefs near Key West and has since been reported Caribbean-wide. In Florida, signs of active white pox disease were observed at Eastern Dry Rocks Reef every year between 1996 and 2000 and at each of the other 7 monitored reefs with living cover of *A. palmata* every year between 1997 and 2002. Observations of white band disease were rare at monitored reefs in the Florida Keys between 1996 and 2002. The Gram-negative faecal enteric bacterium, *Serratia marcescens*, is the cause of white pox (also known as acroporid serratiosis). The bacterium is pathogenic yet commonly occurs in the intestines of humans and other animals and in freshwater and soil. While *S. marcescens* is considered to be ubiquitous in terrestrial and freshwater environments, the distribution and prevalence of this bacterium in the marine environment is unknown and the source of the strain that causes white pox is uncertain. The coral pathogen may originate from an environmental source or from human sewage. Investigations are currently underway to determine the environmental prevalence and ecology of *S. marcescens* in offshore tropical and coral reef environments and to elucidate a source of the coral pathogen in the Florida Keys (from Kathryn Patterson Sutherland, kathrynp@uga.edu, and James Porter).





## PREDATOR PLAGUES

Predator plagues such as COTS are increasingly reported around areas of human activities with 2 strong hypotheses advanced:

- the plagues may be initiated and certainly exacerbated by either over-fishing of key starfish predators, and/or
- increases in nutrient runoff from the land favours the planktonic stages of the starfish.

The increasing frequency of COTS outbreaks continues despite decades of scientific study in the Pacific and Australasia and the cause of these plagues remains unclear. The negative effects of COTS are exacerbated by many other impacts including pollution, fishing pressures, sedimentation, river runoff, global climate change and associated coral bleaching events. These synergistic pressures lead to widespread, large-scale losses of coral cover and biodiversity, which may ultimately affect the biological and ecological processes of the ecosystem.

The highest densities of COTS in recent years have been on coral reefs in Tanzania and Kenya. Initial reports suggest that the northern area of Bawe was destroyed by COTS within 8 months and that COTS is also rampant around Pange. COTS aggregations of 10-30 individuals per 10 m<sup>2</sup> were reported in the Songo Songo Archipelago in 2004 and further aggregations were seen around Unguja Island (Zanzibar), Pemba, Mafia Island, Dar es Salaam, Tanga, and an isolated reef near St. Lucia, South Africa. COTS have increased one hundred-fold from initial densities of approximately 10 per 1,000 m<sup>2</sup> in 2003 to densities of 10 per 10 m<sup>2</sup> in 2004 in the largest population observed in western Zanzibar in the last seven years. Dive operators have organised some removal efforts yet localised damage exceeds 50% coral mortality with unknown wider implications. Unfortunately, 2004 has also marked the first observation of COTS around the Marine Protected Area of Chumbe Island Coral Park (Box p 185) (from Carol Daniels).

Southeast Asia has experienced COTS outbreaks around North Sulawesi (Bunaken NP and adjacent waters) in 2003 and in central Vietnam in 2002. Loss of coral cover and community structure is occurring in Bunaken NP, and is presently subject to control by NSW (see box below). Teams of MPA staff, village hookah divers, and local tourist dive operators were quick to respond and collected large numbers of sub-adults and adults in both parks. In Permuteran Bay, Bali, there is conspicuous damage on both natural and artificial reefs from COTS and *Drupella*, which are approaching plague densities but are not conspicuously aggregated. Daily removal of these organisms has been very effective and has prevented further damage (from Jim Porter, jporter@uga.edu).

In the Marshall Islands, COTS have been found in densities exceeding 20 per 100 m<sup>2</sup> with estimates of lagoon populations of 1000/km and some regions showing over 75% coral mortality. A major COTS outbreak is also in progress on Jaluit, opposite the population center of Jabwot with few COTS found on Arno.

Recent outbreaks in Micronesia have resulted in COTS densities up to 10,000/ km of shore, mostly in shallow lagoons dominated by *Acropora*. Local fishermen have also reported outbreaks around Laura, Kalelin, and Woja. A major outbreak of COTS on the GBR is discussed in Chapter 11.



There is an indication of *Diadema* sp. outbreaks in some areas around Nacula Island in the northern part of the Yasawa Islands, Fiji. High numbers of sea urchins (mainly long spine) may potentially be a result of high artisanal fishing pressure.

## INVASIVE SPECIES

Invasions of non-native species in marine ecosystems can be ecologically damaging as well as economically costly should they become established into their new habitats. Although invasive species introductions have been documented on coral reefs, there have been no incidences of deleterious effects or other significant negative impacts on ecosystem processes or biodiversity. The most likely causes of invasive species introductions are:

- the necessary ballast-water exchange for cargo ships traveling long distances between ports releasing gametes, larvae, or juvenile individuals into new systems; and
- aquaria related incidents whereby individuals import specimens from all over the world and release them into the wild after a time in captivity (Box p 37).

With increasing global trade and exportation of marine aquaria species around the world, caution must be taken in coming years to monitor these introductions and to act as soon as they are observed in order to prevent economic and environmental consequences similar to those documented in freshwater and terrestrial systems. Prevention is undoubtedly the best management strategy and anticipation of further releases and subsequent invasions resulting from marine aquarists and the aquarium industry requires education, community outreach, and enforcement efforts. One potentially useful solution involves identification of ‘hot-spots’ of non-native species and their sources of introduction which can maximize the effectiveness of invasion quarantine programs.

Since Indo-Pacific live rock is exported widely and there are live reef tank enthusiasts at low as well as high latitudes, the risk of introduction of Pacific organisms to the tropical Atlantic is high. If fishes can do it, and they have, certainly invertebrates can.

Coral reefs on the islands of Kaua’i, Moloka’i, Maui, Hawai’i and O’ahu were surveyed for the presence and impact of invasive algae, invertebrate, and fish species along 41 sites. Only 26 invasives comprised of 3 species of algae, 19 invertebrates, and 4 fishes were recorded from a total of 486 total taxa. However, the invasive Orange Keyhole Sponge (*Mycale armata*) and Snowflake Octocoral (*Carijoa riisei*) appear to be increasing in both abundance and distribution on some coral reefs. *C. riisei* is overgrowing and seriously impacting Black Corals in the Maui Lanai Channel, causing the mortality of large, sexually mature colonies that are believed to be critical for maintaining reproduction and replenishment of harvestable Black Coral at shallower depths. This expansion requires monitoring and research effort to obtain basic biological and ecological information that may be utilized by management and conservation groups to assist in controlling their proliferation.

Surveys around American Samoa found 28 non-indigenous species (NIS), considerably fewer than have been determined on harbour surveys in Hawai’i or Guam but more than found at each of 4 North Queensland ports. A maximum of 17 NIS occurred at the main dock, comprising about 10% of the total biota identified at the site, and 5 NIS, or 5% of the total biota, were found at the drydock station. Introduced species were found at other sites in the region including Utulei, Onesosopo, Aua, and Leloaloe. By comparison, relatively few introduced species have

### **PROACTIVE AND REACTIVE MANAGEMENT:VOLUNTARY MAINTENANCE OF CROWN-OF-THORNS STARFISH (COTS) OUTBREAK IN NORTH SULAWESI, 2003**

A voluntary COTS removal effort began immediately after the discovery of a population outbreak in late 2003 on a fringing reef at Mokupa area (Pasir Panjang), south of Manado. The Bunaken MPA Authority and surrounding areas joined the control program on the fringing reef, ultimately collecting more than 500 COTS (mostly small adults although some large individuals (>40 cm) were present) from several ha of reef slope. With spawning expected to occur during the full moon periods in the following months, more COTS outbreaks were discovered at a further 26 dive sites, mostly on the islands of Bunaken National Park. Large female COTS can produce millions of eggs, and when aggregated in outbreak densities, high fertilization rates are common. Thus timing of the control program was particularly important: if the COTS were to reproduce there was great potential to overwhelm the Park and damage the coral reefs. To date, a concerted effort by multiple parties has removed more than 2,700 COTS. The prevention of future outbreaks has limited the damage to popular dive sites (e.g. Lekuan I - III where more than 500 COTS have been collected) and reduced the COTS reproductive output (as COTS were removed prior to annual spawning).

Managing coral reefs is a major challenge for present and future human generations. It is inconceivable that local control programs will cause any change in the COTS overall population abundance globally. However, local controls may help to protect crucially important reservoirs of reef biodiversity, such as those in Bunaken NP, and also local people reliant on reef production and tourism. In this regard local villagers should be actively encouraged to participate in such proactive management projects and to develop a sense of stewardship for their local reefs. In places such as Bunaken NP, one of the most strategic MPAs on earth, it is crucially important to protect the good coral areas for their rich biodiversity, ecological function, and economic value to locals and tourism. In so doing, a high marine tourism capacity can be maintained sustainably.

been propagated in the waters of Tutuila, and those that do occur are mostly restricted to inner portions of Pago Pago Harbor and are not invasive in coral reef areas either within or outside of the harbour. A program of periodic rapid assessment and monitoring should be implemented to ensure that potentially invasive introduced organism that may arrive in the future can be detected and intercepted in their early stages of propagation and spread. A further recommendation is to implement a program to inspect the hulls of large craft such as barges moving between harbours and islands that may transport introduced organisms already occurring in Pago Pago Harbor.

Although results indicate introduced marine invertebrates have not seriously impacted Hawaiian or American Samoan coral reefs under most circumstances, it is important to remember that negative impacts can occur unpredictably and rapidly. Introductions of exotic species should

### INDO-PACIFIC MUSHROOM CORALS FOUND ON JAMAICAN REEFS

Researchers recently documented the reappearance of an exotic coral on a Caribbean reef, 37 years after it was originally introduced. While diving on the fore-reef of Discovery Bay, Jamaica (15 m depth) in 2003, 2 individuals of the mushroom coral *Fungia scutaria* were discovered. These free-living corals (11 and 14 cm in length and each contained an extratentacular bud), which comprise a single large polyp are naturally distributed across the western Indo-Pacific. The impact of non-native, or “exotic” species, is considered to be a leading cause of native species extinction and overall habitat degradation. This threat is well documented in many ecosystems, but the presence and effects of exotic species on tropical coral reefs are rarely considered.

*F. scutaria* was brought to Jamaica from Eilat, Israel in 1966 by Thomas F. Goreau, founder of the Discovery Bay Marine Laboratory. He used the fore-reef at Discovery Bay as a “holding tank” for specimens that were eventually used in laboratory experiments. However he died unexpectedly in 1970 and some experimental subjects must have remained on the reef because researchers found and removed a group of 12 individuals there in 1980. Recent surveys show this removal did not eradicate the species from Discovery Bay and amazingly, it has survived 2 of the most damaging hurricanes in Jamaican history, the collapse of the native coral populations, and the subsequent domination of the reef by macroalgae. It is interesting to note that these specimens have been overlooked for more than 20 years on one of the best-studied coral reefs in the world. Although the impact of *F. scutaria* on native species has probably been minimal, the fact that it has survived in this new environment should be viewed as an ominous warning of potential future invasions by other tropical marine species (from John F. Bruno, jbruno@unc.edu).

in all cases be discouraged. Of course, the impact of introduced algae on Hawaiian nearshore reefs has been far more extensive, serious and well documented (from Steve Coles).

A surprising number of non-native fishes have been surveyed on the reefs of Florida, USA; mostly the result of aquarium releases. The presence of 16 non-native marine fish species off the southeastern USA should spur researchers and managers to take several actions. The density and reproductive status of each exotic species must be determined. If the problem is restricted to a few isolated adults, it may be possible to remove all or most of the individuals and prevent the establishment of a viable population (from Brice Semmens, semmens@u.washington.edu). Elsewhere in the region, the Indo-Pacific lionfish (*Pterois volitans*) has been observed with increasing regularity on Bermuda coral reefs since 2000. Approximately 20 individuals, including both juveniles and adults, have been observed in shallow waters, with some of these individuals being removed from the reef, and in deeper waters (50 - 60 m) with the use of remotely operated vehicle sightings and incidental captures in lobster traps. As a result, the abundance of this species in local waters may be greater than first thought yet the significance of lionfish impact on local fish populations is unknown (from Joanna M. Pitt, jopitt@bbsr.edu).

*Tubastraea coccinea* is an Indo-Pacific coral species, that until recently had not been found in Florida, but is now often reported on artificial structures such as wrecks and piers. It has recently its range into the Gulf of Mexico and has been discovered on many wrecks and on natural substrate at one location. Monitoring data suggests that the coral has spread along current paths from Puerto Rico and Curacao and then into the Gulf, moving from platform to platform. It took about 60 years to spread throughout the Caribbean and Gulf to Florida, and most likely spreads by current dispersed larvae. *T. coccinea* was recently introduced to Brazil on mobile oil rigs, along with a second species, *Tubastraea taguensis*, and both species are now invading Brazilian reefs. Because it is an invasive, fouling species, it must compete with other organisms for space. There are no reports of any adverse effects to date although future monitoring and research efforts will provide insight.

Management efforts should focus on preventing the initial introduction of invasive marine species into local waters, their transport between regions, and preservation of the integrity of coral reef species richness, especially in semi-enclosed embayments and other areas most likely to be initially colonized by introduced species.

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## 2. NEW INITIATIVES IN CORAL REEF MONITORING, RESEARCH, MANAGEMENT AND CONSERVATION

CLIVE WILKINSON

### INTRODUCTION

In parallel with the increasing rates of coral reef damage and degradation due predominantly to human activities, there have been major increases in human initiatives to arrest the decline in reefs. These initiatives are a response to the clear evidence of coral reef decline and the knowledge that coral reefs are critical to the livelihoods of approximately 500 million people around the world. The principal role of the International Coral Reef Initiative is to catalyse initiatives in response to assessments made about the status of the world's coral reefs by the GCRMN and its partners. This chapter summarises some new initiatives that have been undertaken in the last few years, with the goals of conserving coral reefs. The list is not complete, but reflects the responses from agencies to requests from the GCRMN.

The major initiative in coral reef management was the increase in high protection from 5% to 33% of the Great Barrier Reef (GBR). The re-zoning followed recognition that a level of 5% as no-take zones was insufficient to conserve the full range of biodiversity on the GBR, particularly in light of evidence that threats from global climate change induced coral bleaching and disease, and the presence of increasing populations of coral predators. The re-zoning process is described elsewhere (Boxes p 13 and 325 and Chapter 11). There are key lessons from the processes used to achieve this high level of protection. The best available scientific advice and information was used during a 48 month consultation process, which involved three phases. The first phase was an informal period of consultation between GBRMPA, scientists and key stakeholders to produce the bioregions and key conservation targets. This was followed by two iterative phases involving input from all interested parties, including the general public. The result was high level of protection, and future assessments of the new management plan will be observed closely by marine resource management agencies around the world. The process and the level of protection of 33% of the GBR may prove to be the benchmark for the future, although the mechanisms may not necessarily be transferred to other countries and regions without careful investigation.

Individuals and agencies around the world have provided the following descriptions of **New Initiatives**. These brief reports have been broadly classified into a number of themes. However, many of the new initiatives include more than one theme. Other New Initiatives are described elsewhere in this Status report. The themes are:

- **Assessment and Monitoring**
- **Coral Reef Research for Management**
- **Coordination and Cooperation**
- **Funding and Support**

### **ASSESSMENT AND MONITORING – NEW INITIATIVES**

Several major international NGOs, recognised that using ‘standard’ scientific surveys to gather the necessary data to select the best sites for MPA designation was too slow and costly, particularly when there is rapid degradation of coral reefs. The Nature Conservancy (TNC) and Conservation International (CI), along with other international NGOs, such as World Wide Fund for Nature (WWF) and the Wildlife Conservation Society (WCS), have developed and applied rapid assessment techniques to measure the biodiversity of key coral reef components, such as corals, fishes, molluscs and sea cucumbers. Similarly they have used such techniques to assess reef health and current and future stresses. The assessments also include a strong component of local community involvement and consultation. These rapid assessments have been critical in defining the ‘hot spots’ of biodiversity, especially in the ‘coral triangle’ of Southeast Asia and the Western Pacific.

#### **Rapid Ecological Assessments: Finding the best location for an MPA**

MPAs are valuable tools to conserve habitats and their biodiversity. Therefore if new MPAs are to be established, then selecting good habitat and sites with rich biodiversity should be a priority. The problem is that thorough biodiversity assessment and habitat mapping is time consuming (it can take years) and very expensive. Rapid Ecological Assessments (REAs) provide a solution. Two major NGOs, The Nature Conservancy and Conservation International have both developed REAs and applied them within the global centre of coral reef biodiversity; the area with the most coral and fish species ie Eastern Indonesia, the Philippines and the adjacent islands of the West Pacific (Papua New Guinea, Solomon Islands and Palau). There are summaries of specific REAs in Chapter 10 on South East Asia and Chapter 12 on the Southwest Pacific.

The REAs were applied to determine the conservation value of areas in terms of marine biodiversity, which is often expressed as the numbers of hard coral species and reef fish species found during a survey. REAs also provide an initial impression of the threat status and level of resource use (especially fishing) on a reef. The goal is to obtain a rapid, reliable assessment in a 2 to 3 week period of intensive work, by using the best available biodiversity expertise. The surveys are usually conducted from a ship moving around a region, which has already been identified by local experts, such as dive tour operators, to be a likely candidate area. The REA team also needs to involve local experts in order to increase their level of expertise and to ensure that the survey results are disseminated to the pertinent communities and governments.

REAs have been conducted to support the TNC Southeast Asia Center for Marine Protected Areas in Raja Ampat (West Papua), Wakatobi (Southeast Sulawesi), Sangihe-Talaud (North Sulawesi) and the Banda islands (Maluku). In Kimbe Bay in PNG and the Solomon Islands REAs were undertaken to develop site conservation plans and ecoregional conservation

assessments. From: Alison Green, The Nature Conservancy, Townsville, Australia and Sheila McKenna, Conservation International, Washington D.C. USA, [s.mckenna@conservation.org](mailto:s.mckenna@conservation.org).

### **Marine Rapid Assessment Program at Conservation International (CI)**

The Marine RAP is a joint program of the Center for Applied Biodiversity Science and the Marine Programs Division at CI. The process assembles a multi-disciplinary team of marine scientists and coastal resource experts (local and international) to quickly assess the biodiversity and conservation opportunities of coral reefs considered to be a high priority for conservation. The rapid surveys provide data to be used by local communities and decision-makers for the creation and management of MPAs. Most of the surveys involve underwater visual transects to collect data on the structure of the reefs, threats to the reefs, biodiversity of key organisms such as corals and fishes, and commercially important species such as sea cucumbers and giant clams. Socio-economic studies are included, with a community outreach component conducted in parallel with the ecological surveys to ensure that local stakeholders are engaged in discussions early and assist in data collection about concerns and attitudes and patterns of use of the marine resources. Researchers or students from government, universities and NGOs are usually involved in the assessments as in-country experts and participants. Recommendations for conservation are based on an analysis of the biological data within the context of the socio-economic information. Recommendations are aimed at establishing a realistic range and level of activities for the area that will ensure protection of biodiversity. Results and recommendations from the surveys are reported to all local stakeholders using brochures and on-site visits, and published in both English and a local language within a year in the *RAP Bulletin*. Contact: Sheila McKenna, Conservation International, 1919 M St. NW, Washington, DC, USA, [www.biodiversityscience.org](http://www.biodiversityscience.org) and [www.conservation.org](http://www.conservation.org), [s.mckenna@conservation.org](mailto:s.mckenna@conservation.org)

### **Rapid and Permanent Monitoring of Coral Reefs of the Remote U.S. Pacific**

Access to remote reefs in the Pacific is often hazardous, subject to dive safety and time constraints, and involves the high cost of ship-based expeditions. Monitoring of the remote U.S. Pacific islands by joint FWS and NOAA expeditions is limited to a maximum of one visit per year, one hour per dive, three dives per day and a maximum depth of 15-20 m per dive. Monitoring requires a balance between *spatial monitoring* which minimizes temporal variability and *temporal monitoring* which minimises spatial heterogeneity. Rapid spatial and temporal (time-series) survey protocols were developed to accommodate both these dimensions: broad-scale towed-diver and rapid ecological assessments (REAs) over brief time intervals for spatial monitoring; and repeated surveys at permanently marked sites for temporal monitoring. Several strategies were needed to locate previously established transects and ensure sufficient data collection in an hour: use of non-corroding stainless steel pins hammered into reef and glued down with double-barrelled epoxy; placing stakes at 5 m intervals to ease observations; marking the start of each transect with two stakes; taking thorough notes of landmarks, GPS coordinates and depth and keeping transects along a precise depth contour; using digital cameras and a 2 sq. metre photo-quadrat frames to record corals and macro-invertebrates along a 50 m transect line; and using a calibrated survey tape to accurately position quadrats at metre intervals along the line. Data collected from the quadrat photos included visual and computed estimates of live coral cover, generic coral diversity, mean coral diameter, mean frequency, and size class distribution (based on long diameters of each coral with its centre within the 1 m wide swath of the transect line). To date, 91 transects have been established with some already surveyed 4 times since 2000. More than 90% of transects were located and resurveyed during subsequent annual visits. From: Jim Maragos, U.S. Fish and Wildlife Service, Honolulu, [Jim\\_Maragos@r1.fws.gov](mailto:Jim_Maragos@r1.fws.gov)



## ATLANTIC AND GULF RAPID REEF ASSESSMENT (AGRRA) ANALYSES FOR 1998-2003

The AGRRA program is a multinational collaboration developed at the University of Miami by a group lead by Robert Ginsburg. Small teams of trained observers use a standardised methodology to quickly collect quantitative data to assess the condition of coral reefs in the wider Caribbean. They work at multiple scales and focus on stony corals, fishes and algae; the key structural and functional elements of coral reefs. Survey sites are selected in habitats of maximum reef development (typically shallow reef crests and intermediate-depth front reefs), and are preferably representative of the local area. The results presented below are for 313 front reefs (FR) sites at 5-15 m in the 15 assessment locations, each having between 10 and 45 separate surveys performed between 1998 and 2003.

Live coral cover in the front reef sites varied over the Caribbean, and ranged from  $8 \pm 4$  % ( $n=73$  transects/12 sites) in southern Florida (Biscayne Bay and the Florida Keys) in 2003, to  $32 \pm 10$  % ( $n=157$  transects/26 sites) off the Caribbean coast of Panamá (western Kuna Yala and Bocas del Toro) in 2002. Thus the regional differences were independent of the year of survey. Nevertheless, coral cover at some of the early survey sites has showed a considerable decline from bleaching and/or disease following the 1998 El Niño event that particularly affected the Andros reef tract, Bahamas and Akumal, México.

The total number of bleached coral colonies larger than 25 cm in diameter, was 6 times higher in 1998-1999 ( $12.8 \pm 11.0\%$ , 136 sites at 8 locations and more than 11000 colonies measured), than in 2000-2003 ( $2.1 \pm 1.4\%$ , 177 sites at 7 locations and almost 8000 coral colonies measured). Nevertheless, not all regions were affected by the 1998 El Niño event. The prevalence of diseases was clearly correlated with bleaching, regardless of year, varying between 2000-2003 during below average bleaching years (13,012 corals in 222 sites at 9 locations); and  $7.9 \pm 6.4\%$  in 1998-1999 during above average bleaching (6482 corals in 91 sites at 6 locations). The most commonly reported diseases were 'white plague' and 'black-band' in 1998-1999; when bleaching was also highest. Recent partial mortality of the outer surfaces of coral was also greater in the 6 locations with more bleaching ( $7.0 \pm 7.5\%$ ), than in the 9 locations that were below the average ( $2.7 \pm 1.9\%$ ).

Coralline algae were relatively more abundant than benthic macro-algae in 3 large areas (windward Netherlands Antilles; Turks and Caicos Islands; Lighthouse Atoll, Belize), and densities of the important algal grazing sea urchin, *Diadema antillarum*, were very low ( $<0.1/m^2$ ) on most reefs; but the populations appeared to be rebounding in some areas, especially Jamaica.

The biomass of algal grazing fishes (parrotfish and surgeonfish) longer than 5 cm varied on the front reef sites between  $1,061 \pm 394$  g/100 m<sup>2</sup> off the North, West and Southwest of Jamaica and  $7,427$  g/100 m<sup>2</sup> in the Windward Netherlands Antilles (Saba, Saba Bank, St. Eustatius, St. Maarten). Biomass estimates of the commercially important predator fishes (groupers and snappers) ranged from  $163 \pm 250$  g/100 m<sup>2</sup> in Jamaica to  $2,853 \pm 2,289$  g/100 m<sup>2</sup> off southern Cuba (Archipiélago Jardines de la Reina); this is difference of 17 times on reefs in adjacent islands.

The ranking using the 8 AGRRA indicators of coral reef health (live coral cover, % diseased corals, total (recent + old) partial mortality, macroalgal index, coralline algal abundance, *Diadema* density, herbivorous fish biomass, carnivorous fish biomass) from the 'best reefs' to the 'worst reefs' produced the following order: Windward Netherlands Antilles > Grand

Cayman + Little Cayman > Golfo de Batabanó, Southwest Cuba > Turks and Caicos Islands > Lighthouse Atoll, Belize = other parts of Belize ~ Jardines de la Reina, South central Cuba > Virgin Islands ~ Biscayne Bay + Florida Keys, Florida > Andros, Bahamas, > Archipiélago Sabana-Camagüey, North Central Cuba ~ Quintana Roo, Mexico > Panamá > Jamaica. [ > , better than; = , equal; and ~ , about the same]. This ranking has a strong affinity with the level of human pressures on coral reefs; with particularly heavy pressures on Mexican and Jamaican reefs compared to much lower pressures in the Netherlands Antilles and the Cayman Islands. From: Judith Lang, Kenneth Marks Ocean Research and Education Foundation and Rosenstiel School of Marine and Atmospheric Science, University of Miami, USA, JandL@rivnet.net

### **Scientific Monitoring to Support Management of the Marine Aquarium Trade**

Sustainable management of the marine aquarium trade requires regular monitoring of both collection areas and control sites. A partnership between Marine Aquarium Council (MAC), the Global Coral Reef Monitoring Network (GCRMN) and Reef Check developed a set of scientific monitoring protocols to measure reef health, fishing levels, impacts on stocks, and success of no-take reserves in collection areas. The Marine Aquarium Trade Coral Reef Monitoring Protocol (MAQTRAC) is based on Reef Check methods and designed to provide managers with species-level data to assess the effects of collecting fish and invertebrates on the health of coral reefs. MAQTRAC was successfully field tested in 2002 and 2003 in many Asia-Pacific locations. MAQTRAC is now a prerequisite for gaining international certification under the MAC Ecosystem and Fisheries Management Standard.

MAQTRAC starts with a wide-area survey using manta tow to select the site, followed by belt transects and timed swims to count fish and invertebrates and estimate size classes. Line transects are used to assess the living and dead coral cover. A typical survey includes 3 to 5 sites in a collection area with 3 to 5 surveys at each site, making 9 to 25 surveys per area. The methods can be modified to suit each country or collection area, but a core set of standard methods is retained. The protocols include assessing 'control' sites where there is no collection. The land and water areas of the location are recorded for the future reference, using still photos and videotapes. Monitoring also includes measures of harvest levels, catch per unit effort (CPUE) for each collection method, collection mortality levels, and any damage caused to the habitat during collection. These data are used to develop fishery management recommendations. However, there are some limitations: the surveys may not produce sufficient data for fish stock assessment models in areas with low numbers of target species; other types of fishing may confound the results; and using size classes as a proxy for age is problematic for fish that stop growing once they reach a certain size. The intention is to collect and analyse regular, high quality data so that clear trends above natural variation in each fishery can be detected and used to inform resource management decisions, such as total allowable catch limits for communities. MAQTRAC results have already been applied to fishery management in the Philippines. For example, a yield-per-recruit analysis showed that a striped damselfish (*Dascyllus aruanus*) was being over-fished in one area, whereas many other species were fished at sustainable levels. MAQTRAC results are being used to develop zoning, including no-take reserves as required by the MAC Certification process, and can inform decision-making about gear restrictions and access limits. MAQTRAC is a practical tool to detect changes in aquarium species and will be used to monitor coral reefs where MAC Certification is requested. From: Marine Aquarium Council, info@aquariumcouncil.org, www.aquariumcouncil.org and Reef Check, rcheck@ucla.edu, www.reefcheck.org

## CORAL REEF RESEARCH FOR MANAGEMENT - NEW INITIATIVES

### Targeted Research and Capacity Building

The Coral Reef Targeted Research and Capacity Building (TR) program has been established to address fundamental information gaps in our understanding of coral reef ecosystems, so that management options and policy interventions can be strengthened globally. Although opinions abound as to the causes of coral reef degradation, the cumulative and interactive effects of different stresses on coral reefs and the implications for long-term sustainability of these ecosystems are simply unknown. While resource managers struggle to maintain a balance between use and conservation in deciding among complex tradeoffs, we do not know enough about the fundamental factors affecting coral reefs in many areas to make practical management decisions. Moreover, we are not adequately equipped with the understanding and the tools needed to manage and plan for changes brought about by the transformation of these ecosystems; especially over the past 30 years.

The collective efforts of many of the world's leading coral reef scientists will be coordinated for the first time to address outstanding questions about the health and resilience of coral reefs. The Program, supported by the Global Environment Facility, the World Bank, The University of Queensland, the Intergovernmental Oceanographic Commission of UNESCO, the United States National Oceanic and Atmospheric Administration (NOAA) and research institutions in Mexico, the Philippines, and Tanzania, aims to: A) address key gaps in knowledge and technology required for ecosystem-based management of coral reefs; B) promote learning and capacity building in countries where coral reefs are found; and C) effectively link science to management and policy. The TR program will be implemented in phases over 15 years, with an initial focus in four coral reef regions: Mesoamerica; Southeast Asia; Eastern Africa; and Australasia, to establish and strengthen Centres of Excellence for science based management in these regions.

To address key knowledge gaps, the TR Program will support targeted investigations carried out by scientific working groups comprised of developed and developing country researchers. The working groups will be coordinated around 6 key themes:

1. Coral Bleaching and Local Ecological Responses
2. Connectivity and Large-Scale Ecological Processes
3. Coral Diseases
4. Coral Restoration and Remediation
5. Remote Sensing
6. Modelling and Decision Support

A Synthesis Panel of scientists and other professionals will be responsible for the overall quality and direction of the research. They will ensure that the research is responsive to management, is integrated across themes and regions, and that the results are linked to other disciplines, such as economics, sociology and law to inform policies and governance arrangements at the local, national and regional scales. The research objectives of the 6 working groups are summarised below:

### 1. Bleaching and Local Ecological Responses

Corals bleach in response to a range of environmental stress, from localised, anthropogenic stress (like declining water quality, sediment and nutrient runoff, changes in salinity and

pH) to climate change-related stress. While it is known that corals bleach when sea surface temperatures exceed their thermal tolerance levels, the mechanism is poorly understood. Understanding the physiology of bleaching in corals and the differential tolerance of algal symbionts to heat and other forms of stress may explain why some corals bleach more readily than others. It may also shed light on questions of adaptation and whether corals may develop resistance to environmental change through changes in the relative proportion of strains of heat-tolerant zooxanthellae that colonize them. Unravelling these relationships is essential to understanding current changes in patterns of coral diversity and reef community structure and to predicting changes that will occur in the future, under various scenarios of global change. The goal is to help reef managers: refine early warning systems for bleaching; stimulate development of bio-indicators of different kinds of stress; and refine projections of future change on coral reefs and the implications to society.

## **2. Connectivity**

Coral reefs are patchily distributed in the oceans and connected by currents that move in complex and variable ways, particularly in coastal waters and in atoll chains. These currents transport the following: coastal sediment and pollutant run-off; nutrients; and especially the pelagic larvae of most reef species. Connectivity measures the flux of these items between locations. Coral reef managers must understand how nutrients, sediments, pollutants, and larvae arrive at and leave their coral reef areas. Most of the transfer of non-living materials is determined by local and regional hydrodynamics. The transfer of organisms is more complex since there are two components: the passive transport by currents; and additional movements due to the sensory and behavioural responses of the larvae. The most important component in larval recruitment is ensuring that there are upstream breeding populations.

A knowledge of connectivity patterns among coral reef organisms is essential to carry out site-based management of these and associated ecosystems, and to improving the design and implementation of networks of MPAs. Most MPA design and implementation uses 'educated guesses' to select the appropriate size and location, but there is little information to determine whether these guesses are correct. Pressures on reefs will continue to increase with growing coastal populations, and more direct exploitation of reef resources, therefore it is increasingly important that the establishment of MPAs be designed using well determined patterns of connectivity between target populations. Explicit data on demographic connectivity are essential to develop models of recovery rates from broad-scale disturbances, such as massive bleaching events, severe hurricanes, outbreaks of disease or chronic over-fishing. Thus, the Connectivity Working Group will assess the sources of larvae, the transport and dispersal patterns, and finally the successful recruitment processes into the receiving population.

## **3. Disease**

There has been an unprecedented increase in coral disease over the last 20 years, which has contributed significantly to major coral losses. Disease outbreaks cause not only coral loss, but also cause significant changes in community structure, species diversity and abundance of reef organisms. While disease-related damage of coral reefs has been well documented in the Caribbean, the status of disease throughout the Indo-Pacific is largely unknown. Preliminary surveys in Australia, the Philippines, and East Africa reveal significant and damaging new diseases in all locations surveyed. What has prompted this rapid emergence of coral disease? Current research indicates that there is a connection between climate warming and increased incidence of disease, and disease outbreaks are threshold phenomena associated with warming

environments in many ecosystems. Coral reefs appear to be among the most susceptible due to a very narrow thermal threshold for coral health. The coral bleaching during the 1998 El Nino was the most massive and devastating ever recorded, and it is probable that much of the mortality was due to opportunistic pathogens, which accelerated the death of bleached corals.

It is probable that deteriorating environmental conditions influence disease by altering host-pathogen interactions. For example, warmer waters could affect basic biological and physiological properties of corals, and change the balance between opportunistic pathogens and the natural ability in corals to resist them. Other stresses include nutrient loading, which could enhance pathogen growth, and sedimentation, which could decrease coral resistance. Little is known about the organisms that cause disease in corals. Of the 18 or so disease symptoms described, the infectious agent is known for only 5, and reservoirs have only been identified for black band disease and aspergillosis. Exploring even basic questions is hampered by: A. the global nature of the problem; B. an overall lack of resources; and C. a lack of expertise and technology in developing countries. In response, the Coral Disease Working Group will: a) identify major coral diseases; b) assess the impact of coral disease on coral reef biodiversity and community structure; c) explore prevalence of disease in stressed environments and the role of chronic stress in the incidence of disease; d) assess the range of known coral pathogens; and e) evaluate effectiveness of various antimicrobial agents in controlling the spread of disease.

#### **4. Restoration and Remediation**

Recent degradation of coral reefs has stimulated greater attention to remediation and restoration mechanisms for reefs that have been damaged, especially through human pressures. The early initiatives focused more on creating artificial reefs, or more accurately, 'fish-aggregating devices' in areas without existing coral structures to enhance fisheries production or promote dive tourism. While these initiatives are still being expanded, more recent attention has been directed towards restoring degraded coral reefs through a wide range of remediation and restoration mechanisms. These include habitat modification, coral transplantation, species re-introduction, and recruitment potential enhancement. Some interventions involve large-scale structures designed to facilitate natural colonization of reef species, while others use simpler and cheaper approaches. Reef remediation and restoration will continue to have a more important role in reef recovery in the future, but the technologies are still being developed, and not ready to implement at large spatial scales.

The underlying principle of the Restoration and Remediation Working Group is that removing the source of stress is the first priority toward restoration. However, if large areas of reefs have been degraded and natural recovery is not predicted in the short-term, it may be essential to enhance recovery through artificial means. The Group is examining the efficacy and cost effectiveness of restoration and remediation techniques, including the following: the scientific protocols necessary to design and implement restoration strategies; baseline data for developing effective criteria; the efficacy and feasibility of restoration and remediation techniques; prospects for enhancing natural recovery; and opportunities to combine reef remediation with small and micro-enterprise at the local level.

#### **5. Remote Sensing**

Most remote sensing of coral reefs has been conducted on an *ad-hoc* basis with little consistency or recognition of the limitations for wide scale application. For example, some aspects of coral reef health can be resolved on shallow reefs in French Polynesia, but it is not known whether

these can be applied in Jamaica, where the reefs have different organisms, are in deeper water, and where there is more suspended sediment in the water column. Without an assessment of the limitation of coral reef remote sensing, the technology may be oversold or deployed for unrealistic management objectives, resulting in an inappropriate use of financial resources.

The Remote Sensing Working Group will measure the limitations of coral reef remote sensing by combining modelling and field experiments. Models will predict the ability of a remote sensing instrument to detect the slight differences in bottom reflectance that distinguish corals from macro-algae. The challenge is to combine knowledge of the physics of light passing through the water, with the interaction of light between complex mixtures of reef organisms. The methods developed in the computer graphic industry are used to divide coral structures into thousands of individual patches, each of which has a particular reflecting surface. Sunlight is reflected and scattered in predictable directions on the reef and it is possible to calculate the signal recorded by the sensor of the net light that reflected back through the water and atmosphere. Computer models will be refined and tested in the laboratory and the field conditions in a large-scale remote sensing experiment.

The group will provide tools to identify various coral reef habitats and possibly predict the cover of corals and algae on a reef, using high resolution imagery and direct field surveys. There is a wealth of satellite and photographic data for reefs, with some from World War II. The group will try to improve methods for detecting changes in reef condition indirectly using remote sensing to assist managers quantify the rate of change in coral reef habitats over large spatial scales at different time intervals.

Recent remote sensing research has improved the detail of reef maps, but the interpretation of these maps for management and assessing biodiversity has received little attention. The Targeted Research project will improve taxonomic capacity within the Centres of Excellence to allow scientists to prepare habitat maps for priority areas in the region and to provide technical assistance to the other scientific working groups. This Working Group will compile many oceanographic and atmospheric remote sensing products in an International Oceanographic Atlas and make them available for coral reef and coastal management within a single website.

## **6. Modelling and Decision Support**

The Modelling and Decision Support Working Group aims to create an integrated model of the human-based coral reef ecosystem at each site. The group will assist decision makers and local reef users understand the dynamics of the whole system; both the biophysical and the socio-economic components, of which they are a part. The task is multi-disciplinary, multi-scaled and highly spatial. It deals with the complexity of biophysical coral reef system drivers, together with the equally complex human socio-economic aspects. The research is within the new discipline of complex systems science that started in the 1980s and is an area of active research in analytical and modelling techniques. There are many institutes, major government research initiatives and university centres and consortia around the world promoting this approach; some will be involved in this component. Not all the effort is directed at sustainability issues, but also at breaking down stress-response relationships to identify cause and effect of coral reef decline. Complex systems are rarely predictable, and modelling them will require constructing a series of clusters of sub-models to help understand dynamics between sub-components of the system, which can serve as building blocks in the construction of the whole. Clusters of models are particularly effective when several disciplines are involved, or when the questions posed are



evolving. In some traditional 'unified' model domains, such as oceanography or meteorology, where the range of disciplines is restricted and the questions clear, clustering is becoming the strategy of choice.

This exploration can become an integral part of the policy development process in an ongoing iteration between scientists and decision makers. Using visualization techniques involving maps and other spatially explicit media will help engage different classes of users and help them to understand the tradeoffs of different coral reef use options. Through modelling, it is possible for decision-makers, not only see the consequences of their policies, but also identify synergies across sectors, which can reinforce sustainable outcomes for coral reefs. Faced with alternative scenarios, coral reef managers are in a better position to optimise environmental, social or economic objectives and to select the most cost-effective interventions to mitigate unwanted impacts. More information is on: [www.gefcoral.org](http://www.gefcoral.org).

### **ROLE OF MANGROVES AS NURSERY HABITAT FOR CARIBBEAN REEF FISH**

Studies in the western Caribbean on 4 atolls and on the Belize Barrier Reef showed that mangrove forests could influence fish populations on nearby coral reefs. The principal conclusions were:

- most reef fish species have no functional dependency on mangrove nurseries with the possible exception of the largest herbivore in the Caribbean, the rainbow parrotfish (*Scarus guacamaia*);
- mangroves can strongly influence the community structure of fishes, even though most species do not depend on the extent of mangroves near the reefs, and some fish species which never use mangroves as nurseries can be influenced indirectly because they interact with other species that benefit from mangroves;
- the standing stock of fishes using mangrove nurseries is often considerably greater when there is a reef close to the mangroves. An example is the biomass of bluestriped grunt (*Haemulon sciurus*), which was 2000% greater on patch reefs, 650% greater on shallow fore-reefs and 55% greater on outer *Montastraea* reefs at 10 m depth. Other species of haemulids, snappers and parrotfish also benefited from the extent of nearby mangroves.

It is not clear why some species migrate from the lagoon to the fore-reef. They may seek food sources that are more abundant on the reefs, larger fish may outgrow the shelter provided in nursery habitats, or the fish may need greater access to ocean currents to disperse their larvae after spawning. Many species, including the bluestriped grunt live in seagrasses until they are around 6 cm long, then move to the mangroves. However, they appear to move to the seagrasses at night to feed, because 63.5% of the gut contents of juveniles consisted of tanaid shrimp, which are more prevalent in the zooplankton and sediment of seagrass beds. After growing in the mangrove nurseries, which provide a more plentiful food supply and refuge from predators, the fish migrate to the patch reefs. In the case of reefs with no nearby mangroves, the bluestriped grunt move directly from seagrasses to patch reefs, but at a much smaller size and lower density (260 per hectare compared to 3,925 per ha in mangrove-rich areas). As the biomass of predators is often greater on reefs than mangroves (30 tonnes km<sup>-2</sup> versus 18 t km<sup>-2</sup>), the chances of small grunt surviving may be lower if they migrate directly to reefs. The biomass of bluestriped grunt is significantly greater on patch reefs, shallow fore-reefs and *Montastraea* reefs when there are mangroves nearby. The case is clearer for the

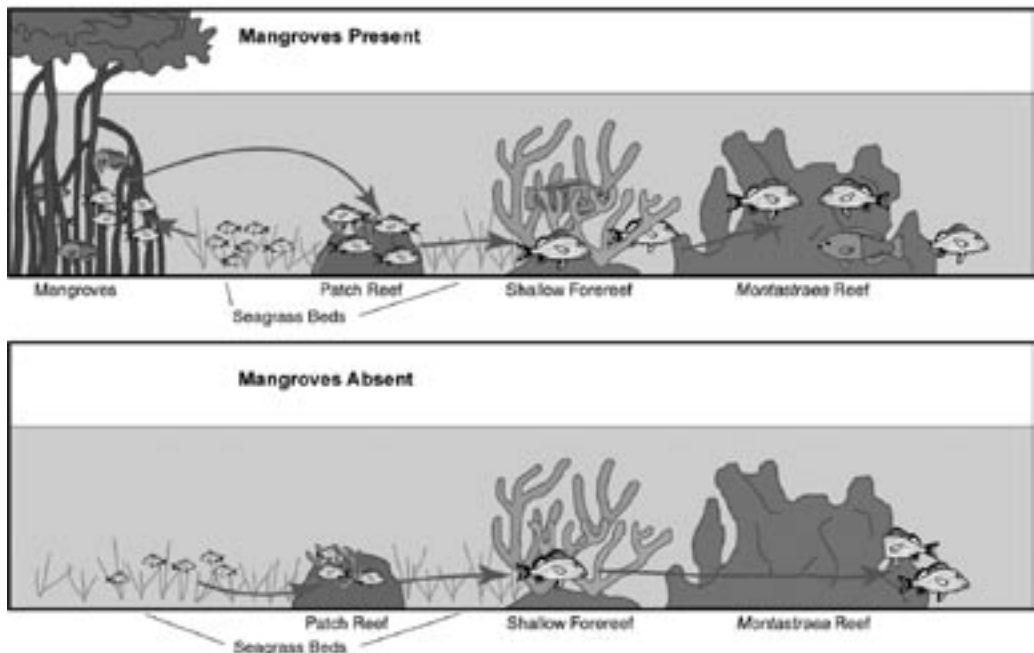


rainbow parrotfish (*S. guacamaia*) because it has a functional dependency on mangroves and is rarely seen on reefs when there are no mangroves nearby. From Peter Mumby, University of Exeter UK; p.j.mumby@ex.ac.uk; full report on [www.ex.ac.uk/msel](http://www.ex.ac.uk/msel)

### Coral Reef Research by the Wildlife Conservation Society (WCS)

The WCS has maintained scientific programs in coral reef conservation since 1991. Their programs are focused in 3 major regions of study: the western Indian Ocean, with most projects focused on the fringing reefs of Kenya; the Meso-American Barrier Reef, with projects focused on reef atolls of Belize; and the high diversity reefs in Indonesia and Papua New Guinea. A program in Madagascar is commencing as part of the western Indian Ocean program. The society has a coral research laboratory at the Osborne Aquarium and Columbia University in New York City. The major objectives of the programs are to:

- determine the effects of marine parks, global climate change, fishing, and indigenous management on fisheries catches, species diversity and reef ecology;
- develop methods to restore coral reefs that have been degraded by over-fishing, pollution or coral bleaching;
- assist the organisation of relevant government agencies and social organisations in developing sustainable resource use for coral reefs;



Where mangroves are present, the bluestriped grunt (*Haemulon sciurus*) moves from the seagrass beds to the mangroves where they continue to grow in a relatively safe environment, before moving to the ‘riskier’ adult habitat of coral reefs. In the absence of mangroves, the grunt move directly from the seagrass beds to the reefs at a smaller, more vulnerable size, which may explain the smaller populations of several reef fish including grunts, snappers and parrotfish on reefs with no adjacent mangroves. The large rainbow parrotfish (*Scarus guacamaia*) is less likely to occur where there are no nearby mangroves.

- foster the professional development and training of marine scientists in coral reef ecology and management practices; and
- contribute to the coordination and general development of coral reef conservation and science in the tropics.

Depending on the major threats and needs for conservation science in each region, these themes differ slightly between study sites and over time.

From: Tim McClanahan, Wildlife Conservation Society, Kenya, [tmccclanahan@wcs.org](mailto:tmccclanahan@wcs.org).

### **ReefBase: A Global Database on Coral Reefs**

ReefBase is a global information system on coral reefs that was developed by The WorldFish Center and the International Coral Reef Action Network (ICRAN). This online database ([www.reefbase.org](http://www.reefbase.org)) stores quality information on the location, status, threats, and management of coral reefs in nearly 100 coral reef countries and territories. ReefBase serves as the central database for the GCRMN, and provides valuable information services to managers, policy-makers, researchers, conservationists, educators and students around the world. Some of the most popular features of ReefBase include: a vast collection of coral reef related literature (currently over 21,000 references, with some 3,000 publications available for download); and an interactive mapping system (GIS) with maps and reef-related datasets that can be downloaded via the Internet and edited. ReefBase continues to expand and develop as the world's leading information system on coral reefs. In 2005, there will be a particularly strong thematic focus on coral reef fisheries and socio-economic data. As a first step in a new, modular strategy, ReefBase will open a new field office in the Pacific, where ReefBase staff will collaborate with local partners to develop an extensive knowledge base on coral reefs catering to the needs of Pacific Island communities. More information is on ReefBase at: [www.reefbase.org](http://www.reefbase.org), contact: Marco Noordeloos, ReefBase Project, The WorldFish Center, Penang, [m.noordeloos@cgiar.org](mailto:m.noordeloos@cgiar.org).

### **People and Coral Reefs: A Partnership for Prosperity and Coral Reef Health**

The International Coral Reef Action Network (ICRAN) is a global partnership to assist developing countries by working with user communities to ensure that activities on coral reefs are sustainable. The main goal is to reverse the trend of serious degradation of coral reefs. ICRAN focuses on strengthening the capacity of local communities to manage their own marine and coastal resources through monitoring and communication, and recognising that coral reef decline can be reversed. ICRAN was established through a grant from the UN Foundation to carry out the ICRI agenda to conserve the coral reefs of the world. The partnership consists of CORAL - the Coral Reef Alliance, GCRMN, ICRI Secretariat, Marine Aquarium Council, Reef Check, South Pacific Regional Environment Program, The Nature Conservancy, UNEP and the UNEP Regional Seas Program, UNEP-World Conservation Monitoring Centre, The WorldFish Center, World Resources Institute and WWF, which bring together a strategic alliance of experts with scientific and conservation experience in coral reefs.

The ICRAN action plan recognises the importance of scientific, traditional, cultural, and economic aspects of conservation. The goal is to implement these aspects through direct on-the-ground action throughout the world's major coral reef regions through a network of sites (see Special Sites at the end of regional chapters), as well as at regional and international levels, by means of a strategy that includes alternative livelihoods, training, capacity-building and the exchange of scientific, economic, traditional and social information. This emphasises the notion that the overall success depends significantly on dialogue and the development of

a consensus between all local and national stakeholders. Private sector engagement is critical for any successful coral reef initiative, thus the ICRAN partnership has placed emphasis on building bridges with industry.

ICRAN's current mission is based on three key interlinked components:

- **Reef management** – ICRAN assists local communities and coral reef managers by providing support and resources to enhance management capacity and build on successful techniques. In addition to support at a local level, ICRAN offers a forum to exchange community experiences and knowledge with other coral reef managers and policy makers worldwide;
- **Global coral reef monitoring and assessment** – building on new and existing scientific data, learning from traditional local knowledge and the lessons of practical experiences – GCRMN and Reef Check are critical partners to this component; and
- **Communications and knowledge dissemination** – the ICRAN assessment and information dissemination activities are designed to produce, and make available the knowledge needed to empower stakeholders, decision-makers, scientists and educators for the sustainable management of coral reefs.

Contact: Kristian Teleki, [icran@icran.org](mailto:icran@icran.org), [www.icran.org](http://www.icran.org)

#### **FOUR MAJOR NGOs FORM A LEARNING PARTNERSHIP ON MPA NETWORKS**

The Johannesburg World Summit on Sustainable Development in 2002, the World Parks Congress in 2003, and the Convention on Biological Diversity in 2004 all called for networks of MPAs to conserve biodiversity and habitats. Four major NGOs (Conservation International - CI, The Nature Conservancy - TNC, the Wildlife Conservation Society - WCS, and the World Wildlife Fund – WWF) have responded by forming a new learning partnership to exchange information and ideas on creating and sustaining MPA networks.

MPAs are recognised as valuable tools for coastal and marine habitat protection and biodiversity conservation. The international community is calling for the creation of ecologically- and socially-coherent networks of MPAs that are resilient and representative. However, there are major challenges to effectively manage and sustain individual MPAs. Moreover, there is also much to learn beyond these challenges about designing, adaptively managing, monitoring, and financing MPA networks. In response, these 4 NGOs decided to combine their efforts and provide a focused learning program among institutions across sites and countries around the world.

The partnership has defined two broad learning questions:

1. what will it take to design effective MPA networks? and
2. what does it take to create and maintain a positive enabling environment to support the establishment and sustainability of effectively-managed, representative networks of MPAs?

The partnership is founded on the belief that the process is most effective when the participants come together to identify strategies and lessons so that they can learn from each other, and focus on the specific questions and activities that will add most value to their work. A small group of field staff from the NGOs and their local partners in each of 6-10 key MPA networks around the world will promote learning among group members and conduct joint activities addressing specific learning questions from their programs. Contact: Roger McManus CI - r.mcmanus@conservation.org; Scott Smith, TNC - ssmith@tnc.org; Liz Lauck WCS - llauck@wcs.org; Kate Newman WWF - kate.newman@wwfus.org.

### **HELPING MPA MANAGERS COPE WITH CORAL BLEACHING: REEF RESILIENCE TOOLKIT**

When the 1998 global coral bleaching event hit, many reef managers were unprepared and confused. Well-managed areas were being devastated while some areas outside their protection had survived; there seemed to be no pattern or logic. This event stimulated a major shift in planning of MPAs, with the concept of putting emphasis on managing coral reefs that are **resistant** (do not bleach when others nearby may) or **resilient** (bounce back quickly afterwards) to bleaching. The Nature Conservancy and partners have developed the R<sup>2</sup>- Reef Resilience Toolkit to help MPA managers and policymakers respond to the threats from global climate change by enhancing their planning and management strategies. The multimedia, CD-ROM Toolkit outlines the steps necessary to select, protect and monitor coral reef communities that are likely to be resistant or resilient to bleaching and/or be sites with fish spawning aggregations.

The R<sup>2</sup> Toolkit aims to help managers build resilience into coral reef conservation so that the systems can survive the anticipated global changes and continue to provide goods and services for the local communities. It is now predicted that bleaching and other global threats will increase, and this has prompted a recommendation to focus on protecting resistant or resilient coral reefs as one counter to the potentially devastating future threats. Another important consideration is to focus on economically important areas, like tourist reefs and fish spawning aggregations.

The resilience strategy has 3 critical components: Application; Training; and Science.

- Application is to apply the concepts and tools to MPA network design and management, while building capacity for coral reef conservation and facilitating information exchange.
- Training is essential to share the resilience concepts and management strategies at global scales and improve integration of the principles into coral reef management to improve tropical marine conservation.
- Science provides the underpinnings of the Toolkit by defining and improving the resilience principles through field testing and tracking the evolving science.

These tools will assist reef managers play a larger role in preparing for and responding to a mass bleaching. But many reef managers work in remote areas and lack the resources and skills to respond to emerging global threats. Moreover they do not have access to scientific advice and evidence to guide their responses to a bleaching event. Therefore, the R<sup>2</sup> Toolkit includes the science underlying the resilience principles and is presented so that it can be used in remote areas. TNC now seeks mechanisms to deliver the Toolkit into the hands of as many managers as possible and then use this network of managers to field test and refine the Toolkit. This Toolkit will be provided to all reef managers, if requested. To order a copy, contact TNC Marine Initiative at [resilience@tnc.org](mailto:resilience@tnc.org).

## **WEB-BASED REEF ADVISORY SYSTEM (WRAS) FROM REEF CHECK**

The new WRAS system was created to give all Reef Check team members and registered users instant access to monitoring results and interpretation. WRAS has five components: a searchable GIS database, a charting function to view the results of any given survey, a scorecard for each indicator, a statistical function that allows comparison of one site or region with any other, and an advisory system that provides basic information on problems detected and possible solutions. In practice, teams can submit their data via webform or email and then start using WRAS to compare e.g. their site with the nearest site or with all sites in their country -- from that year or previous years. WRAS is a major step forward in providing rapid information on coral reef health to coral reef managers. WRAS is a joint project of Reef Check, ReefBase, University of Southern California and Rhode Island Coastal Resources Center. It can be accessed from [www.ReefCheck.org](http://www.ReefCheck.org).

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## **THE IMPORTANCE OF THE PRIVATE SECTOR IN CORAL REEF CONSERVATION**

An essential component for the effective management of coral reef MPAs is to build working partnerships between local park managers and other key stakeholders. Studies have shown that MPA managers need the support and involvement of local resource users if they are to achieve their conservation objectives. A primary reason for engaging private sector members, like local dive operators, as partners in coral reef protection is because these business owners are quite powerful in their communities. A healthy economy is important for policymakers in their efforts to develop sound economic policy for communities.

Destinations with MPAs and reserves tend to have healthier marine ecosystems with higher fish biomass, density and larger predatory fish. They usually have more invertebrates and higher biodiversity than unprotected areas. Therefore, marine recreation providers, such as the dive industry, are natural allies of park managers for conservation because their business success depends on having a healthy coral reef to attract customers. Tourists will repeatedly visit these reefs and create sustainable revenue and livelihoods for the community. There are successful partnerships between marine park managers and the private sector in tourist venues like Bonaire, Bunaken, and Palau where enlightened self-interest and tourism dollars have supported coral reef conservation.

The Coral Reef Alliance (CORAL) has developed a 'Sustainable Marine Recreation' training program to build conservation alliances among park managers, marine tourism operators and community groups. They conduct workshops and facilitate discussions over a variety of

topics, including coral reef ecology, solutions to coral reef degradation, and sustainable business practices. The workshops provide a forum for stakeholders to meet, voice their concerns, and collaborate to create relevant local solutions to current reef problems. In August 2003, CORAL held a two-day workshop in Bali, Indonesia for more than 40 participants from 20 dive businesses and several NGOs. These participants identified anchors as a primary cause of damage to local reefs, and first steps towards developing a mooring buoy plan were initiated. Less than one year later through their hard work and dedication, the Bali dive community successfully installed 49 mooring buoys to protect some of the most popular and beautiful coral reefs. One dive operator commented, "Until this course, I never realised the full implications of what we do as dive operators when it comes to saving coral reefs... nor how big a part the dive community can play." CORAL held several workshops in Fiji, Palau, and the Federated States of Micronesia in 2003, and all have resulted in substantial increases in community support for coral reef conservation and MPAs. These mutually beneficial public-private partnerships enable all stakeholders to capitalise on their shared interests and work together to keep their coral reefs healthy. From: Sherry Flumerfelt, The Coral Reef Alliance, San Francisco, [sflumerfelt@coral.org](mailto:sflumerfelt@coral.org).

### **REEFS AND POVERTY: FROM POLICY TO PRACTICE**

Coral reefs occur in more than 100 countries and underpin the livelihoods of many millions of people in developing countries. In some areas, particularly small island developing states (SIDS), the dependence is extremely high, and many people depend on reef resources as a safety net to alleviate poverty. Other people regularly depend upon reef resources at certain times of the year as a **key-stone resource** to ensure that they escape the worst poverty. The number of reef dependent people is increasing, due to natural growth, migration to coastal areas and a loss of land-based opportunities. These people are extremely vulnerable to reef degradation and many are becoming poorer as reefs are threatened by the effects of:

- climate change on the coast;
- habitat destruction, sedimentation and pollution from multiple sources including coastal development, tourism and agriculture and forestry; and
- over-exploitation of fishery resources and destructive fishing practices.

Coral reef degradation has been a major international issue and the focus of many international agencies and their partners in governments, multi-lateral agencies and NGOs for many years. There is also a growing recognition of the interrelationships between poverty and the sustainable use of the natural environment. This has emerged in numerous policy frameworks such as Agenda 21, CBD, the Durban Accord, WSSD and the Millennium Development Goals (MDG). The MDG, which are the central guiding policy framework for many international development agencies, place specific emphasis on both the eradication of extreme poverty and hunger, and ensuring environmental sustainability.

Closely linked to this emerging policy consensus, is a growing call for more practical guidelines to put pro-poor conservation policy into practice. For example, the recent ICRI meeting in Okinawa discussed how the Code of Conduct for Responsible Fisheries could be more explicitly translated into practical guidance for the equitable and sustainable use of coral reefs. The demand for such guidance is likely to increase, especially to address specific issues such as the need to create alternative livelihoods for the ever-increasing number of reef users. From: Jock Campbell and Emma Whittingham, IMM Ltd, Exeter, UK, [www.ex.ac.uk/imm/](http://www.ex.ac.uk/imm/)



## COORDINATION AND COOPERATION - NEW INITIATIVES

### **IUCN: Ensuring Survival of Coral Reef Species**

The IUCN Species Survival Commission is accelerating efforts to identify fish and other species that are threatened with extinction, as fisheries and other pressures increase and damage habitats. The Commission has developed a network of marine experts and a marine program of work, with some components pertinent to coral reefs. The coral reef-related Specialist groups focus on marine turtles, sharks, groupers and wrasses, and coral reef and Caribbean fishes. Threatened marine species, identified by these and additional SSC experts, are included in the IUCN Red List of Threatened Species, the world's most authoritative and comprehensive list of species at risk of extinction. There is an urgent need to expand this to identify species in need of conservation, and evaluate the current and potential future threat of coral bleaching and other stresses on coral reef species and ecosystems.

**Extinction Vulnerability in Coral Reef Fishes:** Over-exploited coral reef fish species are vulnerable to population depletion, and possibly to extinction. The IUCN- Species Survival Commission recognised the urgent need to raise awareness and concern about the real survival risks for coral reef fishes, and to translate this into proactive management. The IUCN Coral Reef Fishes Specialist Group is developing a collaborative, multi-institutional project, the Global Assessment of Reef Fishes, to determine the IUCN Red List, or threatened, status of several thousand species. This will include the creation, maintenance and use of a database on life history, ecological and behavioural characteristics, exploitation levels and threats, and other variables for use in making assessments. The Assessment will map species distributions, which will be essential for making Red List assessments.

**Sharks and Coral Reefs:** Shark and ray populations are rapidly being depleted for the lucrative shark-fin trade. The IUCN Shark Specialist Group was established in 1991 to interact with international conventions like CITES, and organisations such as FAO to provide leadership for the conservation and management of sharks. They are preparing Red List assessments and providing technical, scientific and policy advice. A major concern is shark finning and the group is working to promote regional and international cooperation to regulate this practice. Reef sharks have become an important focus, as they are top predators, vital to maintain a healthy balance of reef ecosystems, and are major features for ecotourism ([www.flmnh.ufl.edu/fish/organizations/ssg/ssg.htm](http://www.flmnh.ufl.edu/fish/organizations/ssg/ssg.htm)).

**Groupers and Wrasses – Vulnerable Coral Reef Fishes:** The IUCN Specialist Group for Groupers and Wrasses was established in 1998 to focus on these two particularly vulnerable and economically valuable reef fish families (approximately 1,000 species). More than 20 species are considered threatened, and Group members are active in species assessments and biological research on more vulnerable species. They work with the Society for the Conservation of Reef Fish Aggregations to document the current status and exploitation history of spawning aggregations, in order to strengthen the case for protection of aggregations and aggregating species. The Group is running an awareness campaign for the humphead wrasse and assisted in developing of Standards of Good Practice for the trade ([www.hku.hk/ecology/GroupersWrasses/iucnsg/](http://www.hku.hk/ecology/GroupersWrasses/iucnsg/), [www.scrfa.org](http://www.scrfa.org)).



**Marine Turtles and Coral Reef Ecosystems:** The IUCN Marine Turtle Specialist Group was founded in 1966 in response to a growing recognition of the endangered status of marine turtles. The mission is to develop and support strategies, set priorities, and provide tools to promote and guide the conservation of marine turtles, their ecological roles and habitats. The group will investigate the integration of sustainable use protocols into conservation, and determine recovery criteria for distinct populations. The group membership assesses population status and assists with the design and implementation of management and conservation activities, often relying on a mixture of traditional and current scientific knowledge and the latest technical advancements ([www.iucn-mts.org/](http://www.iucn-mts.org/)).

Contact: Kristin Sherwood, IUCN Global Marine Program, Washington DC, [ksherwood@iucn.org](mailto:ksherwood@iucn.org), or Amie Brautigam, IUCN-SSC Marine, [thomsen.brautigam@prodigy.net](mailto:thomsen.brautigam@prodigy.net).

### **CORDIO (CORAL REEF DEGRADATION IN THE INDIAN OCEAN) REFUNDED**

CORDIO was initiated 1999 as a response to the massive mortality of corals in the Indian Ocean during the 1998 global coral bleaching event. Coral reefs support a considerable proportion of the populations and economies of countries in the Western and Central Indian Ocean, through fisheries, tourism and large-scale investments. Using funding provided by the Swedish International Development Co-operation Agency (SIDA) and other donors including IUCN, WWF and the Government of Finland, CORDIO supports 45 monitoring and research projects, conducted by more than 50 scientists at local institutions in 11 countries throughout the Indian Ocean. CORDIO is a locally driven, regional initiative, designed to build the necessary capacity to enable scientists and managers of the Indian Ocean to obtain valuable data to improve the management of their coral reef resources in a more sustainable manner. The CORDIO program addresses several sustainable development issues: food security; alternative livelihoods; poverty reduction; and contributes to global activities addressing climate change and biodiversity conservation. The activities of CORDIO are designed around these themes:

- **Ecological monitoring:** using existing national monitoring programs or through the establishment of new programs, scientists and management agencies in the countries involved in CORDIO are assessing the condition of their coral reefs and associated habitats in order to make informed management decisions and evaluate the success of existing management plans. The data generated by these monitoring programs contribute to global coral reef initiatives such as GCRMN and ReefBase;
- **Socio-economic monitoring:** the short and long-term impacts of coral reef degradation on households, industries and national economies can be assessed through socio-economic monitoring programs. These help the search for options to mitigate the impacts;
- **Targeted research:** scientists and institutions involved with CORDIO are doing specific research to address aspects of climate change related coral bleaching, its damage, resilience and recovery in corals, options for restoration and management, and sustainable use of coral reefs and their resources; and
- **Alternative livelihoods:** pilot projects have been successfully implemented in some countries to alleviate pressure on coral reef resources by developing alternative sources of income for families dependent on those resources.

The activities of CORDIO are co-ordinated through 3 regional Nodes in Colombo, Sri Lanka, Mombasa, Kenya and Victoria, Seychelles and one central node in Kalmar, Sweden. Program

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## **THE 2010 TARGET OF THE CONVENTION ON BIOLOGICAL DIVERSITY**

2010 is the deadline set by the 188 member countries to the Convention on Biological Diversity, to achieve a significant reduction in the rate of biodiversity loss by an effective and coherent implementation of the Convention on Biological Diversity. The 2010 target is critical to turning the tide of species loss and resource depletion and ensuring the continued development and survival of life on Earth, including the human species. Collective and sustainable use of resources will result in the alleviation of poverty and the improvement of life on Earth.

The GCRMN, through the Status of Coral Reefs of the World Reports, is the main data and information provider for measuring progress towards the CBD 2010 targets as it applies to coral reefs. Each report will provide an update of progress made towards the target.

**Progress made towards the 2010 target in 2004:** Coral reefs and their associated biodiversity continue to decline. Most coral reefs around the world are being damaged by over-exploitation, land-based pollution and sedimentation. Climate change is predicted to cause massive destruction of coral reefs in the next decades. If 'business as usual' continues, the 2010 target for coral reefs will not be reached. Instead, there will be a loss of coral reef diversity.

**Actions that need to be taken now to reach 2010 target:** Action to reverse the trend of coral reef decline would require development of new, well-managed MPAs, reduction of fishing pressure, halting destructive fishing practices, and increased community involvement in monitoring and management of reef resources. On a global level, the reduction in greenhouse gas emissions that are driving global climate change are required.

## **THE CBD COP-7: RESULTS OF RELEVANCE TO MARINE AND COASTAL PROTECTED AREAS AND CORAL REEFS**

The 7<sup>th</sup> meeting of the Conference of the Parties (COP) to the Convention on Biological Diversity was held in Kuala Lumpur, Malaysia, 9 - 20 February 2004. Representatives from 162 countries, international organisations, indigenous and local community organisations and NGOs, attended the meeting. They adopted 36 decisions, which are available on: [www.biodiv.org/decisions/](http://www.biodiv.org/decisions/).

Amongst the important results of COP 7 was decision VII/5 on Marine and Coastal Biological Diversity. This decision adopted the elaborated program of work on marine and coastal biological diversity, which includes new material on marine and coastal protected areas, mariculture, high seas biodiversity, and coral bleaching. In addition, relevant activities from the Plan of Implementation of the World Summit on Sustainable Development (WSSD) have been incorporated into the program of work.

Marine and coastal protected areas (MCPAs) created substantive discussion and resulted in recommendations on national systems of MCPAs and guidance on how countries could develop such systems. The COP noted the low level of development of MCPAs and agreed that

the goal for work related to MCPAs under the Convention should be the establishment and maintenance of MCPAs that are: effectively managed; ecologically based; and contribute to a global network of MCPAs, building on national and regional systems, and including a range of levels of protection. The decision VII/5 on marine and coastal biological diversity and the decision VII/28 on protected areas, adopted targets for developing such MCPA systems by the year 2012, echoing the commitment made in the WSSD Plan of Implementation. The COP agreed on the establishment of a national framework of MCPAs consisting of areas allowing sustainable uses and areas where extractive uses are excluded.

The COP also underlined that there is an urgent need for international cooperation and action to improve conservation and sustainable use of biodiversity in marine areas beyond the limits of national jurisdiction, including the establishment of MCPAs consistent with international law and based on scientific information. Seamounts, hydrothermal vents, cold water corals and other vulnerable ecosystems were identified in paragraph 59 of decision VII/5 as threatened areas in need of rapid action to address those threats in the context of the precautionary approach and the ecosystem approach. As one of the next steps in the process, the Convention's Ad Hoc Open-Ended Working Group on Protected Areas will consider this issue in 2005.

The CBD work plan on coral bleaching was also updated by COP-7, and is contained in Appendix 1 of the elaborated program of work (decision VII/5, Annex I). The aim of this updated work plan is to be increasingly action-oriented in undertaking management actions and strategies to support reef resilience, rehabilitation and recovery. The amendments recognise the need to manage coral reefs for resistance and resilience to episodes of raised sea temperatures and/or coral bleaching, and including these in MPA network design. The new elaborations to the CBD work plan on marine and coastal biological diversity represent a major step forward in developing strategies for reducing biodiversity loss in oceans and coastal areas.

## **FUNDING AND SUPPORT - NEW INITIATIVES**

### **France Launches CRISP - Coral Reefs Initiative for the South Pacific, 2005**

This project aims to reduce the local and global threats to Pacific coral reefs and the peoples who depend on them for their livelihood by offering a more sustainable future. CRISP was designed as 3 year units starting in January 2005 with a contribution of EUR 5 million (USD 6 million) from the French Agence Française de Développement and French GEF (French Fund for World Environment), supplemented by a matching amount from Conservation International (CI), United Nations Foundation (UNF), World Wide Fund for Nature (WWF) and the French Ministry of Foreign Affairs (MAE). CRISP is developing strategies and projects to preserve the biodiversity of Pacific coral reefs to ensure that their economic and environmental services are sustained for local and global communities. The initiative will strengthen regional integration between the developed and developing countries, with the major partners being: SPREP (South Pacific Regional Environmental Program); University of South Pacific; Secretariat of the Pacific Community; WorldFish Center; International Coral Reef Action Network; and French research institutes, Institute of Research for Development, International Research Center for Agronomy and Development, the Ecole Pratique des Hautes Etudes through the Moorea laboratory (CRIOBE) and the French universities of New Caledonia and French Polynesia. About 15 Pacific countries are included, including 3 French overseas territories (New Caledonia, Wallis and Futuna, French Polynesia), operating within the French Initiative for Coral Reef (IFRECOR).

The specific objectives of CRISP are to:

- improve the understanding of the biodiversity, status and functioning of coral reefs;
- implement actions for large-scale protection and management of coral reefs;
- develop the economic potential of coral reef use and biodiversity values; and
- disseminate information and knowledge, strengthen capacity and organisation of local, national and international networks throughout the Pacific.

To meet these objectives, CRISP will combine: i) cross-cutting network activities with conservation and economic development field projects; ii) research, planning and development; iii) contributions from different disciplines, including biology, ecology, economics, sociology, law and anthropology. Simultaneously, the project will target terrestrial and marine factors influencing coral reef function, including watershed management and wastewater treatment. Rather than create new structures, CRISP will strengthen existing partners willing to cooperate actively in the region.

Specific CRISP Components are:

- integrating Marine and Coastal Protected Area development and watershed management;
- integrating the extension of coral reef research, identification of potentially active marine substances, networking of reef monitoring and restoration; and
- coordinating knowledge management and project management.

The principal expected outcomes are: improved knowledge of coral reefs, including the effects of global change, to assist cross-disciplinary interactions for decision makers and planners; the protection and sustainable co-management of significant areas of coral reefs that comply with defined scientific and social criteria; the consolidation of the economic potential of coral reefs, demonstrated by examples of sustainable fishing and aquaculture, tourism, biodiversity development, etc; and strengthened collaborative networks of people of the French overseas territories, developed countries and the small island states of the Pacific. From Dominique Rojat - [www.afd.fr](http://www.afd.fr), and [rojatd@afd.fr](mailto:rojatd@afd.fr).

## **REEF CHECK RESPONSIBLE CORPORATE PARTNERS**

The major goal of Reef Check is to directly involve corporations in marine conservation. Reef Check works with corporate partners on projects that allow them to apply their skills and expertise to conservation problems. Reef Check has developed key partnerships with environmentally responsible corporations that share our vision of marine conservation. Since 2000, Quiksilver, the lifestyle boardriding company has provided a berth for a Reef Check scientist on their global 5-year expedition, 'The Crossing'. As a result, Reef Check had been able to survey remote sites throughout the Indo-Pacific and Caribbean that would otherwise be unreachable. Reef Check has partnered with Body Glove on the Kona Classic event, that combines underwater photography with coral reef education for kids, and are designing additional educational outreach programs. Body Glove and Tusa, the dive equipment manufacturer, have provided substantial donations of wetsuits and dive gear respectively for Reef Check teams. Finally, Reef Check partnered with MacGillivray Freeman Films in the development of 'The Coral Reef Adventure', an award-winning IMAX film. The large interactive lobby displays for this film have been donated to Visitor Centres at several marine protected areas around the world. From: Gregor Hodgson, Reef Check Los Angeles, USA, [gregorh@reefcheck.org](mailto:gregorh@reefcheck.org).



### 3. THE STATUS OF THE COLD-WATER CORAL REEFS OF THE WORLD

EDITED BY STEFAN HAIN, EMILY CORCORAN

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This text is largely based on an updated and revised summary the UNEP-WCMC Biodiversity Series report no. 22 *Cold-water coral reefs, Out of sight – no longer out of mind* by A. Freiwald, and colleagues and published in 2004 by UNEP-WCMC, Cambridge, UK.

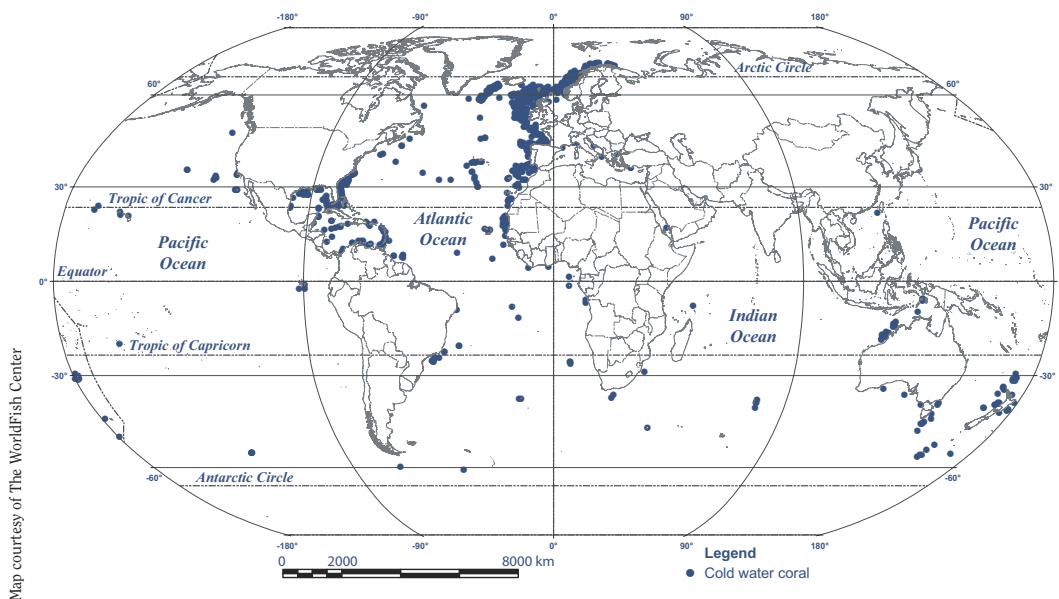
#### **ABSTRACT**

Recent underwater studies have shown the beauty and high diversity of cold-water coral reefs, which are comparable in size and structural complexity to the warm-water coral reefs of the tropics. This chapter describes the various cold-water coral ecosystems, together with their known and potential global geographical distribution. Observations from several locations around the world illustrate the state of these reefs and highlight their vulnerability to threats caused by human activities, which have already destroyed or affected a large number of cold-water coral reefs. It is the aim of this chapter to raise awareness about cold-water coral reefs and put forward some recommendations for action to conserve, protect and sustainably manage these fascinating, but fragile ecosystems.

Although their distribution is still poorly known, current information indicates that they occur in coastal waters, along the edges of continental shelves and around offshore sub-marine banks and seamounts in almost all of the world's seas and oceans. Because of their extreme vulnerability, there is a need for urgent and precautionary action to conserve and sustainably manage these cold water coral reefs. Such action includes the prohibition of destructive fishing practices, including bottom trawling, and the establishment of marine protected areas (MPAs).

#### **INTRODUCTION**

The existence of cold-water coral habitats has been known for centuries, however detailed observations and research on them in their natural surroundings are mostly concentrated in the last decade. When scientists around the globe gained access to increasingly sophisticated instrumentation, such as manned and remote operated submersibles, they were able to explore



*The map shows the known distribution of cold-water coral reefs around the world, based on the limited number of confirmed observations. This map should be regarded as a conservative compilation of locations. More reefs are being discovered each year.*

deep-water environments. Their findings have challenged conventional wisdom. Coral reefs are not confined to shallow and warm tropical and sub-tropical regions; there are a variety of coral ecosystems thriving in deep, dark and cold-waters around the globe. Some of these cold-water corals construct banks or reefs as complex as those in tropical areas. Analyses have confirmed that some of these living banks and reefs are up to 8,500 years old, and the geological records show that cold-water coral reefs have existed for millions of years.

Cold-water corals grow in dark deep waters; hence they have no light-dependent symbiotic algae in their tissues and must depend on currents to supply food, like organic matter and zooplankton. Many of these cold-water corals produce calcium carbonate skeletons that resemble bushes or trees to support colonies of polyps; these structures increase their ability to capture food more efficiently. The result is a complex three-dimensional, forest-like habitat that provides a multitude of niches for the associated animal communities.

It is only recently that an understanding has developed of the complexity of these cold-water coral ecosystems, because most of them are largely hidden and ignored and can only be observed with complex and expensive equipment. Like their tropical counterparts, cold-water coral reefs are home to thousands of other species, in particular sponges, polychaete worms (or bristle worms), crustaceans (crabs, lobsters), molluscs (clams, snails, octopuses), echinoderms (starfish, sea urchins, brittle stars, feather stars), bryozoans (sea moss) and fishes. Most of the studies have been carried out at higher latitudes, but there are now reports of cold-water coral reefs off the coasts of Africa, South America and in the Pacific, indicating that they occur in all seas and oceans. Many of these 'wait' to be explored and studied in more detail to fill the knowledge gaps of marine deep-water ecosystems and reef-forming processes.



Researchers are also beginning to realise that coral reefs represent a continuum. At one end, the evolution of light-dependent symbioses has allowed corals to survive under low nutritional regimes in the shallow, clear waters of the tropics. Cold-water corals are at the other end of the spectrum, thriving as carnivorous animals, adapted to capture food in deeper and colder waters. Unfortunately, as the understanding of the distribution, biological dynamics and rich biodiversity of cold-water ecosystems expands, there is clear evidence that many of these vulnerable ecosystems are being damaged by human activities. Undoubtedly, the greatest and most irreversible damage is due to the increasing intensity of deep-water trawling that relies on the deployment of heavy gear, which ‘steamroll’ over the sea floor destroying virtually everything in its path. There is also concern about the potential effects of oil and gas exploration, in particular the potentially smothering effects of drill cuttings.

Cold-water coral reefs have recently become an important topic on the political agenda of various national and international bodies, due to the realisation that reefs in many locations have already been destroyed or severely damaged. There is a great risk that these unique and spectacular marine habitats could be gone in one or two decades, if corrective action is not taken quickly.

## DESCRIPTION AND SIMILARITIES

Cold-water coral reefs, like their tropical warm and shallow-water counterparts, are built predominately by stony corals (*Scleractinia*). A comparison of the similarities and differences between warm and cold-water coral reefs shows that many of the management issues are similar, however, visualising the problems in cold, dark deep waters is considerably more difficult than for tropical coral reefs.

*This table lists some of the similarities and differences between cold-water and tropical coral reefs.*

Characteristic	Cold-water coral reefs	Warm-water coral reefs
Distribution	Potentially in all seas & at all latitudes	In subtropical & tropical seas between 30°N & 30°S
Number of states, countries & territories with corals	41 so far	109
Area Covered	Unknown: studies indicate global coverage could equal, or exceed warm-water reefs	Conservative estimate is 284,300 km <sup>2</sup>
Country with largest coral reef area	Unknown: at least 2,000 km <sup>2</sup> estimated in Norwegian waters	Indonesia (51,020 km <sup>2</sup> )
Largest reef complex	Unknown: Røst Reef (100 km <sup>2</sup> ) (discovered 2002) in northern Norway, probably the largest	Great Barrier Reef (more than 30,000 km <sup>2</sup> ), Australia
Temperature range	4° - 13°C	18° - 32°C (mostly)
Salinity range	32 - 38.8 (‰)	33 - 36 (‰)
Depth range	39 - 3,383m	0 - 100 m
Nutrition	Uncertain: probably suspended organic matter & zooplankton	Suspended organic matter and photosynthesis

Characteristic	Cold-water coral reefs	Warm-water coral reefs
Symbiotic algae	No	Yes
Growth rate	Up to 25 mm/year	Up to 150 mm/year
Number of reef-building coral species	Around 6	Around 800
Reef composition	Mostly composed of one or a few species	Mostly composed of numerous species
Age of living reefs	Up to 8,500 years	Up to 9,000 years
Status	Unknown: most reefs studied show physical damage; some reefs in NE Atlantic completely lost to bottom trawling	30% irreversibly damaged; another 30% at severe risk of being lost in the next 30 years
Rate of regeneration/recovery	Unknown: very slow growth rate indicates that possible regeneration /recovery may take decades to centuries for damaged reef to regain ecological function	Slow (years to decades): regeneration /recovery may lead to reduced coral diversity, species composition shifts or phase shifts to algal dominated ecosystem, especially when human pressures are evident
Main threats: natural and induced by climate change	Unknown: climate change may cause large changes in current systems affecting the living conditions	Increased episodes of higher sea surface temperatures will lead to more widespread & lethal coral bleaching
Main threats from human activities	<ul style="list-style-type: none"> <li>■ Bottom fisheries</li> <li>■ Oil &amp; gas exploration &amp; production</li> <li>■ Placement of pipelines &amp; cables</li> <li>■ Others e.g. pollution, research activities, dumping</li> </ul>	<ul style="list-style-type: none"> <li>■ Over-fishing &amp; destructive fishing (especially with bombs &amp; cyanide)</li> <li>■ Pollution &amp; sedimentation from land based sources &amp; coastal development</li> <li>■ Tourism &amp; anchoring</li> </ul>
Ecological importance	Reefs provide habitat & feeding grounds for many deep-water organisms; probably have recruitment & nursery functions for commercial fish species. The species richness on these reefs & full ecological importance unknown	Estimated 1 million plant & animal species are associated with warm-water coral reefs. There are approximately 4 000 coral reef fish species (a quarter of all marine fish species)
Socio-economic importance	Unknown: initial observations suggest important for local fisheries, including coastal line/net fisheries & deep-water fisheries (especially around seamounts)	Reefs provide coastal protection and livelihoods for more than 1 billion people; net potential benefits provided by reefs estimated at US\$30 billion/year
International awareness and attention	Increased over last 2 - 3 years	Increasing over last 1-2 decades, especially after bleaching events in the 1990s; more than 100 non- & intergovernmental organisations involved

## KEY COLD-WATER CORAL SPECIES

Colonies formed by stony corals (*Scleractinia*) in cold and usually deep waters can vary in size from small, scattered colonies no more than a few metres in diameter to vast reef complexes measuring several tens of metres in height and kilometres in length. Such large and complex reef structures are built by only a few coral species. The critical difference between the cold-water corals and those constructing tropical reefs is that the corals in cold water do not have photosynthetic symbionts, thus are not limited by available light. The limitations are that all cold-water corals rely on capturing food from seawater and live in cold water, which slows biochemical reactions.

In the North Atlantic, the Mediterranean Sea and the Gulf of Mexico, *Lophelia pertusa* and *Madrepora oculata* are the most abundant reef builders. *L. pertusa* forms cauliflower-like colonies measuring up to 4 m across and consisting of thousands of translucent white to yellow, orange or red-coloured coral polyps. As the colony develops, adjacent branches tend to fuse, thereby considerably strengthening the entire framework. *L. pertusa* has a global distribution and is best known from the East Atlantic, stretching from the south-western Barents Sea along the continental margin down to West Africa. The largest cold-water coral reef known so far is the Røst Reef, primarily built by *L. pertusa*, which was discovered in northern Norway in 2002.

Like *Lophelia*, corals of the *Madrepora* group are cosmopolitan; two of this group, *Madrepora oculata* and *M. carolina*, form branched colonies which are generally much more fragile than *Lophelia* and tend to break easily, which limits their capacity to build large frameworks or reefs. However, they are often associated with other reef-building corals such as *L. pertusa* and *Goniocorella dumosa*.

The continental slope off Atlantic Florida and North Carolina is the home of reefs constructed by *Oculina varicosa*. This species can occur in both shallow (where the species often possesses symbiotic algae similar to tropical shallow reef corals) and deep water. The shape of *Oculina* colonies varies from short, stout branches in the surf zone to taller and more fragile spherical, bushy or finger-like structures in deeper areas, which can measure up to 150 cm in diameter.

*Solenosmilia variabilis* is widely distributed in the South Pacific and Atlantic Ocean, whereas *Goniocorella dumosa* is only reported from waters around New Zealand, South Africa, Indonesia and Korea. Both species are the most prominent reef-building species in the southern hemisphere, especially around seamounts and oceanic banks off Tasmania and New Zealand. *G. dumosa* is frequently found in water depths of 300 to 400 m, whereas *S. variabilis* aggregations often occur on the summits of seamounts in 1,000 to 1,400 m. The biology and ecology of both species is poorly known.

*Enallopsammia profunda* is endemic to the western Atlantic from the Antilles in the Caribbean, to Massachusetts in northeastern USA. The species can form massive finger-like colonies up to 1 m thick in 150 m to 1,750 m depth. *E. profunda* is often associated with *L. pertusa*, *M. oculata* and *Solenosmilia variabilis*.

Cold-water coral ecosystems are not exclusively the domain of stony corals. Other groups of corals with solid or calcified skeletons, such as black corals (Antipatharia) or lace corals (Stylasteridae), form branched or tree-like structures in cold water. In addition, there are

numerous groups of soft corals such as precious corals, sea fans and bamboo corals which form rich, strikingly colourful, communities in colder and deeper waters, such as the 'octocoral gardens' off Nova Scotia, along the Aleutians and the North Pacific coasts as well as on seamounts off Canada, the United States, Japan and in New Zealand waters.

These cold-water corals create ecological niches, which favour the settlement and growth of a wide range of other invertebrates, such as sponges, bryozoans, and molluscs. The combination of all these make up the cold-water coral reefs and form preferred habitats for a wide range of other species such as fish and shellfish, including many of high commercial importance.

### **DISTRIBUTION OF COLD-WATER CORALS**

Cold-water coral reefs occur in coastal waters, along the edge of the continental shelf and around offshore sub-marine banks and seamounts in almost all of the world's seas and oceans. They are known from the territorial waters of 41 countries, but this will be an underestimate as there have been few systematic searches. Most studies have been carried out at high latitudes, where these corals are observed from 40 m to depths of hundreds of metres. In tropical areas, warm-water masses overlay the cold, nutrient-rich water, which explains why cold-water coral reefs are usually found at greater depths in these areas.

Cold-water coral ecosystems are defined as 'a large occurrence of corals' at one location. Almost all cold-water coral ecosystems share a number of environmental attributes. Their preferred locations are found where there are suitable conditions:

- Strong topographically guided bottom currents that prevent deposition of sediments; thereby creating current-swept hard substrates that facilitate colonisation by habitat-forming corals. Generally, these grounds are pre-existing rocky heights of various sizes that are obstacles in the current: they can be boulder fields, moraine ridges, drumlins, the flanks of oceanic banks, seamounts, sedimentary mounds and occasionally artificial substrates, such as wrecks and oil rigs;
- The flow of water is funnelled through narrow passages such as straits (e.g. Florida Strait, Strait of Gibraltar, Cook Strait New Zealand) or channels, fjord troughs (e.g. in Scandinavia, New Zealand and Chile) and submerged canyons and gullies; and
- Nearby nutrient-rich waters stimulate the development of high phyto-plankton and zoo-plankton levels, providing a major food source for the coral communities.

### **MAJOR THREATS TO COLD-WATER CORAL REEFS**

Cold-water corals are long lived, slow growing and fragile, which makes them especially vulnerable to physical damage. Since the mid-1980s, the deeper parts of the world's oceans have come under increasing pressure from human activities to exploit biological and mineral resources. Recent surveys of cold-water coral reefs have shown that in many locations, the reefs have already been destroyed or damaged. The main documented and potential sources of threats to cold-water corals are listed below.

#### **Bottom Trawling and other Bottom Fishing**

Fishing gear that is dragged along the sea floor, such as bottom trawls or dredges, is the greatest threat to cold-water coral reefs. Bottom trawling on deep shelves and along the continental margins to 1,500 m depth and beyond has increased dramatically since the late 1980s. Large and heavy gear is used in these operations, with nets as large as 55 m across and 12 m high.

*This list of countries with cold-water corals is certainly not complete, but illustrates the wide distribution of these cold water reefs in virtually all oceans and seas*

Angola	Italy
Australia	Jamaica
Brazil	Japan
Canada	Madagascar
Cape Verde	Mauritania
Chile	Mexico
China	Morocco
Colombia	New Zealand
Cuba	Nicaragua
Denmark (Greenland, Faroe)	Norway
Dominican Republic	Portugal
Ecuador	Russia
France	Seychelles
Ghana	South Africa
Guyana	Spain
Haiti	Surinam
Honduras	Sweden
Iceland	United Kingdom
Indonesia	United States of America
Ireland	Venezuela
	Western Sahara

The bottom of the net opening is weighted by chains or cables with heavy discs or rollers, and they are held open by beams or vanes (known as ‘doors’), which can weigh as much as 6 tons. On a typical fishing trip in the north-east Atlantic, a trawler sweeps approximately 33 km<sup>2</sup> of sea bed.

Although most fishermen try to avoid trawling over large coral reefs and coral-topped carbonate mounds, there is a great deal of direct and collateral damage to coral grounds. Visual observations provide clear evidence that trawl doors plough through the seabed and smash or disrupt corals. Groundline rollers flatten corals and coral-covered boulders, while the strengthened base of the trawl net can tear or break coral further. A single trawl can completely destroy a cold-water coral reef, which has taken thousands of years to grow. Even if not impacted directly, further damage is caused by the sediments disturbed by trawling, which can smother nearby corals.

Although considerably less harmful than bottom trawls and dredges, there are other fishing techniques, such as bottom-set gillnets, bottom-set longlines as well as pots and traps, which come into contact with the sea floor and thereby pose a threat to cold-water coral reefs. In most cases, anchors and weights are used to fix this gear on or near the seabed, causing some physical damage to the fragile reefs. Lost fishing nets and lines are frequently observed entangled in the corals; however, the recovery of such lost gear would certainly cause further damage.

### **Hydrocarbon Exploration and Production**

Exploration for, and production of, oil and gas can have severe, potential effects on coral habitats, including physical impact from the placement of structures (oil platforms, anchors, pipelines), damage from discharges of rock cuttings, drilling fluids and chemicals, or from

discharges from the wells. In areas such as European waters, oil companies are required to conduct environmental impact assessments before carrying out most activities. This has led to the discovery of several cold-water coral reefs, and avoided or reduced the risk of damage to them. However, the challenge is to ensure that such regulations occur everywhere and that the industry works to the highest possible environmental standards.

### **Cable and Pipeline Placement**

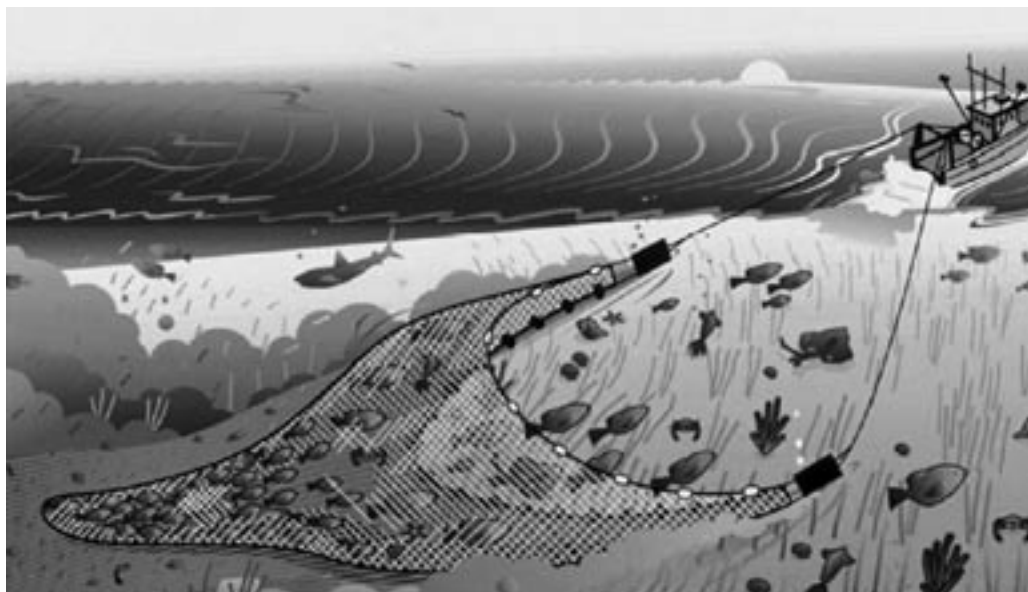
Telecommunication and electricity cables, and oil and gas pipelines crisscross all seas and oceans. In waters shallower than 1,500 m, these cables and pipelines are usually buried within the seabed, especially to prevent accidental damage by trawlers. There is potential damage to cold-water coral reefs from the physical impact of the cables and pipelines themselves, and more importantly the anchors used by the ships during installation. The resuspended sediments from the burying methods can also smother nearby corals.

### **Bioprospecting and Destructive Scientific Sampling**

There has been considerable recent research by scientists, and biotechnology and pharmaceutical companies in deep-water ecosystems. This occurred after they shifted their focus from shallow-water communities to sampling cold-water corals and sponges. Most of this research is with remotely operated submersibles which minimises the potential damage to deep reefs, however, damage does occur, e.g. where sampling gear is dragged over the bottom.

### **Waste Disposal, Dumping and Pollution**

The oceans have long been regarded as a place to dispose or dump wastes. Ropes and fishing equipment are frequently found on cold-water coral reefs, mostly through accidental loss. The deliberate dumping or disposal of material (such as dredged sediments and mining wastes) on coral reef ecosystems may physically damage corals or bury them.



*Trawlers do considerable damage to deep-water coral reefs because the nets and associated gear are specifically designed to keep the net close to the bottom and clear away obstructions, such as corals and sponges.*



The damage to cold-water corals from marine pollution, including environmental toxicants, radioactive wastes and sewage is unknown, however, there is concern in the scientific community that chronic pollution of the ocean will result in damage to many marine ecosystems and result in a loss of biodiversity.

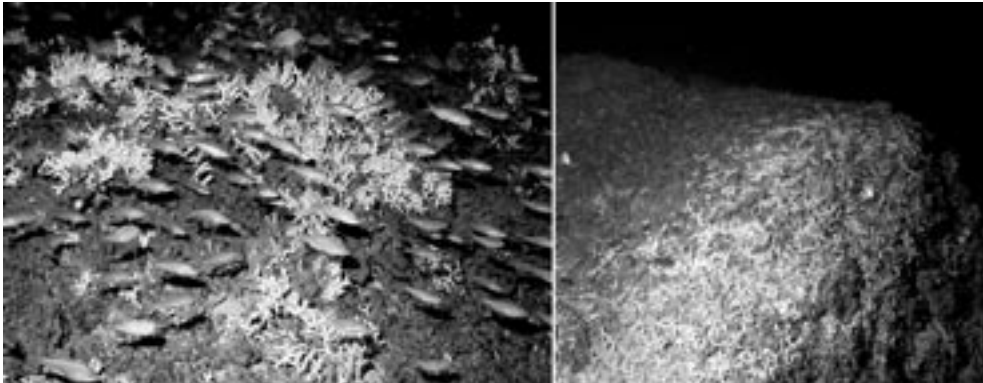
### **Coral Exploitation and Trade**

A number of cold-water corals are exploited for trade, such as precious coral species (*Corallium*) and black corals (*Antipatharia*). The threats originate when specimens are harvested unsustainably or with unselective gear such as coral draggers (an iron bar with chains to trap pieces of coral), which also causes considerable habitat damage.

### **Future Threats**

There are also concerns about several potential and future threats that could damage cold-water coral reefs. There has been considerable discussion of deep-sea mining for minerals, especially manganese rich nodules and mineral concentrates on 'black smokers' in tectonically active areas. While such mining has not started, there is strong potential for adverse effects on corals (e.g. direct damage and re-suspension of sediments).

The capture of CO<sub>2</sub> from the atmosphere and sequestration into deep waters has been proposed as a way of reducing greenhouse gas emissions. It is uncertain whether this disposal would significantly reduce atmospheric CO<sub>2</sub> in the long-term and there are concerns that the dissolution of CO<sub>2</sub> will lower the alkalinity (pH) of seawater, thereby impairing the ability of corals to lay down calcium carbonate structures (Box p 26). The rise of CO<sub>2</sub> levels in the atmosphere is already lowering the pH in seawater, which may already be affecting the calcification of tropical corals and cold-water corals. Climate change may also affect water currents and thus change living conditions for cold-water corals.



*These 2 photographs illustrate what happens when a fishing trawler drags heavy gear over a fragile, deep cold-water coral reef in the Northeast Atlantic. The healthy reef on the left has been reduced to a rubble bed by the heavier rollers and weighted net; destroying a fish habitat.*



## STATUS OF COLD-WATER CORALS: REGULATIONS AND MEASURES

Some countries have recently enacted regulations and measures to protect a few cold-water coral reefs, however, most of the reefs and ecosystems are not protected, and are under serious threat of destruction, especially from bottom trawlers. It is very expensive to examine and survey cold-water coral reefs in their natural deep-water surroundings. Therefore, information on the status of these coral reefs remains incomplete and geographically biased. Concerted studies have only been conducted on these ecosystems during the last 20 years, and these have been predominantly spot investigations to determine the presence of the reefs and associated animals.

The regulations and measures being adopted by some countries and regional bodies to protect and manage vulnerable marine habitats, including cold-water coral reefs, vary considerably depending on the specific threat, the status and location of the reefs. Measures and regulations range from requiring environmental impact assessments prior to activities or the prohibition of bottom trawling on cold-water coral reef areas, to conservation by forbidding all damaging activities on cold-water coral reefs.

Some cold-water coral reef locations have been designated under national and regional legislation as 'habitats of particular concern', 'special areas of conservation' or 'marine protected areas (MPAs)'. MPAs have been used by countries in their territorial and EEZ waters as a tool to protect sensitive or especially valuable marine species and habitats against harmful human activities. MPAs can vary in size and the degree of protection, from strict nature reserves, which are managed mainly for science and wilderness protection, to multiple-use areas that allow for the sustainable use of natural ecosystems compatible with the specific conservation objectives.

The World Summit on Sustainable Development (WSSD) agreed in 2002 to achieve a significant reduction in the current rate of loss of biological diversity by 2010. One of the agreed activities was, by 2012, to establish representative networks of MPAs consistent with international law and based on scientific information. This was adopted by the Conference of the Parties to the Convention on Biological Diversity (CBD) in 2004 (COP-7 Decisions VII/28 on protected areas and on marine and coastal biological diversity). The elaborated CBD program of work on marine and coastal biodiversity outlines the need to designate cold-water coral reef locations as MPAs. Cold-water coral reefs also occur in the international waters of the high seas, beyond national jurisdiction. The protection of these reefs is now the focus of international efforts to protect vulnerable high-seas habitats, consistent with international law including the UN Convention on the Law of the Sea (UNCLOS). This is currently being discussed at the international level, mainly under UNCLOS and the CBD. Specific actions taken by national governments in the Atlantic, Indian and Pacific Oceans are discussed below.

### ATLANTIC OCEAN

Most continental shelves of the north-eastern and north-western Atlantic Ocean have suitable environments for cold-water corals. Some of the reefs found in these regions, especially on the eastern seaboard stretching from Norway to West Africa, are among the best studied and constitute the basis for most of our knowledge on cold-water coral reefs. However, new reefs are being discovered continuously even among these relatively well-known parts of the Atlantic Ocean. The largest *Lophelia* reef so far (about 100 km<sup>2</sup>) was found in 2002.

**Norwegian Shelf, Northeast Atlantic:** There are many cold-water coral reefs along the shelf break and the edges of the deep troughs of the Norwegian Shelf, including the largest and the shallowest *Lophelia* reefs; the Røst Reef is approximately 35 km x 2.8 km, southwest of the Lofoten Islands. There are also several reefs in Norwegian fjords, including the Selligrunnen Reef at 39 m in the Trondheimsfjord. Scientific cruises and fishing reports indicate that the mid-Norwegian shelf sector between 62°30'N and 65°30'N and the shelf break between 62°30'N and 63°50'N contain the densest assemblages of corals, at 200 to 400 m depth.

There has been trawling along the continental shelf break and on the shelf banks since the mid-1980s, including robust rock-hopper trawls, which have allowed larger vessels to fish in rougher and previously inaccessible areas. This has caused the complete destruction of coral reefs in some places

Norway was the first country to implement protection of cold-water corals in European waters. The need for urgent action to protect these reefs emerged after the Norwegian Institute of Marine Research estimated that probably between 30 and 50% of the cold-water coral reefs in Norwegian waters had been partially or totally damaged by bottom-trawling. In 1999, Norwegian fisheries authorities established a regulation for the protection of cold-water coral reefs against fisheries damage. This regulation prohibits intentional destruction of coral reefs, and requires precaution when fishing in the vicinity of known reefs. Furthermore, the regulation gives special protection to particularly valuable coral reefs by totally banning the use of fishing gear which is dragged along the bottom, and may come in contact with the reefs. So far 5 reefs have received this special protection: the Sula Reef; Iverryggen Reef; Røst Reef; Tisler Reef; and Fjellknausene Reef. The shallow Selligrunnen *Lophelia* reef has been conserved by the environmental authorities through the Norwegian Nature Conservation Act.

The Norwegian Government has outlined further measures to protect cold-water coral reefs, including a proposal to protect a selection of reefs against all threats as part of a national representative network of MPAs. The process of establishing this network started in 2001, and is due to end in 2006-2007.

**Rockall Trough, Darwin Mounds and Porcupine Seabight, Northeast Atlantic:** Knowledge of the corals on the Rockall Trough, Darwin Mounds and Porcupine Seabight area to the west of Ireland and the UK has increased considerably as a result of targeted studies funded by: Atlantic Frontier Environmental Network; Natural Environment Research Council (NERC); industrial consortia of the UK (Managing Impacts on the Marine Environment); and European Commission (Atlantic Coral Ecosystem Study) and Environmental Controls on Mound Formation along the European Margin projects.

*Lophelia pertusa* occurs along the relatively shallow flanks of the Rockall Bank and to a lesser degree on Porcupine Bank at 180 to 300 m. The slopes of the Rockall Trough and the northern and eastern parts of the Porcupine Seabight, are covered in coral carbonate mounds at 500 to 12,00 m. These *Lophelia* reefs are associated with clusters of giant carbonate mounds, which rise 10 to 300 m above the sea floor, with the densest living corals on the summits of the mounds, where current flow is generally strongest.

There has been deep-sea fishing over this entire area since 1989. Although no quantitative analysis has been made in the wider Rockall-Porcupine area, the damage from the trawlers has been frequently documented during visual inspections. Some of the carbonate mounds are probably too steep for existing trawling gear, but low relief mounds are much more vulnerable to trawling.

A special area of concern is the Darwin Mounds, distributed across approximately 100 km<sup>2</sup> in the northern Rockall Trough, 185 km off northwest Scotland. These series of mounds in 1,000 m were discovered in 1998 during an environmental survey by a consortium of oil companies and the UK Government. The mounds are most probably 'sand volcanoes' formed by fluid release, and are colonized by *L. pertusa* and a rich associated community. Just 2 years after their discovery, there was direct evidence that the mounds had been trawled. The UK Government requested urgent action through the European Commission in August 2003 and an emergency measure was imposed to prohibit bottom trawling and similar activities within the Darwin Mounds. This action for the conservation and sustainable exploitation of the fisheries resources was taken under the common fisheries policy. In March 2004, the European Council permanently prohibited such fishing in an area of approximately 1,300 km<sup>2</sup>.

The UK intends to designate the Darwin Mounds as a special area of conservation under the European Commission Habitats Directive, however, there is no national legislation to specifically protect cold-water coral species in UK waters. *L. pertusa* reefs now feature in the non-statutory UK Biodiversity Action Plan, which recommends conservation and research on their distribution and designation within MPAs. *L. pertusa* reefs are being considered as nationally important features within a review conducted by the UK Department for Environment, Food and Rural Affairs (Defra).

Ireland has formed a working group of all sectors to determine policy to conserve cold-water corals after evidence was presented of fishing damage in 2001. In June 2003, the Irish Government also decided to protect some cold-water coral under the EC Habitats Directive. The Department of the Environment, Heritage and Local Government is now identifying suitable sites, in consultation with major stakeholders.

**Azores, Madeira and Canary Islands:** *Lophelia* reefs occur off the Canary Islands and often at depths greater than 1,000 m around the Atlantic islands of Madeira and the Azores. These reefs are part of the belt of reefs stretching from Norway to West Africa. After similar evidence of damage from trawlers, the EC proposed mechanisms to protect these vulnerable deep-water coral reefs from trawling around the Azores, Madeira and Canary Islands in 2004. This extends the temporary protection from trawling by a special access regime. The new regulations will guarantee continuity of protection for these areas as part of European Community legislation.

**Cold-water Coral Reefs in Atlantic Canada:** Corals have long been known in Atlantic Canada, because they frequently appear as by-catch in fishing trawls, long-lines and gillnets. The Department of Fisheries and Oceans at the Bedford Institute of Oceanography began studies in 1997 by interviewing fishers and fishing observers on commercial vessels. They extended this with video and photographic observation of cold-water corals collected during research cruises. Cold-water corals are widespread off Nova Scotia, Newfoundland and Labrador, and extend northwards to the Davis Straits.

**Scotian Shelf, Northwest Atlantic:** The Scotian Shelf off Nova Scotia has coral reefs predominantly between 190 and 500 m, with corals frequently caught in fishing gear. The distribution and status of these corals were reviewed in 1997 by the Ecology Action Centre, which identified 3 major areas where closures were implemented on the outer continental shelf and slopes: the Gully, a large submarine canyon on the Scotian Shelf with the highest diversity of coral species in Atlantic Canada; the Northeast Channel, with a high density of gorgonian corals; and the Stone Fence, the first *L. pertusa* reef in Canada.

The Department of Fisheries and Oceans has designated the Gully as the first MPA in Atlantic Canada under the Oceans Act (1997), after draft regulations were released for public comment in 2003. The MPA prohibits damaging activities to protect species in this ecosystem, including deep-sea corals. All activities, including research, will be excluded from one of the three zones. There is little evidence of fisheries damage. The halibut long-line fishery will be permitted to continue in part of the MPA.

ROV (remotely operated vehicle) surveys in 2000 and 2001 in the Northeast Channel, confirmed that octocorals grew in areas with cobbles and boulders, but 29% of all surveys showed colonies had been damaged by long-line and trawl fishing for redfish (*Sebastes*). The Canadian Government declared 424 km<sup>2</sup> around Romey's Peak as a multiple use conservation area in 2002, because of a high density of gorgonian corals in the Northeast Channel. About 90% of the area is now a 'restricted bottom fisheries zone' and closed to all bottom fishing, with the remaining open only to authorised long-line fishing. There is an ongoing observation program to survey the level of fishing activity and any resulting damage.

The first *L. pertusa* reef in Atlantic Canada was found off the Stone Fence at the mouth of the Laurentian Channel in 2003. This is a small reef, 1 km long and several hundred metres wide, but had been heavily damaged by fishing. A 15 km<sup>2</sup> area around the reef has been closed to all bottom fishing under the Fisheries Act to allow the corals to recover.

## US ATLANTIC AND PACIFIC WATERS

Cold-water coral ecosystems and habitats occur along the continental shelf and slope of both the Atlantic and the Pacific coasts of the United States, in Alaskan waters of the Bering Sea, and on island slopes and seamounts in the U.S. Caribbean and Pacific. Currently, there is no U.S. legislation that specifically conserves cold-water corals; although recent bills regarding protection of these resources from trawl fishing damage have been proposed in the U.S. House of Representatives and Senate. The Magnuson-Stevens Fishery Conservation and Management Act governs the conservation and management of fishery resources in the U.S. EEZ from 3 to 200 nautical miles (nm) offshore. It requires the Secretary of Commerce, via the National Oceanic and Atmospheric Administration (NOAA) and 8 Regional Fishery Management Councils, to develop and maintain fishery management plans (FMPs) for resources under their jurisdiction. Although primarily established to ensure sustainable fisheries, FMP measures provide protection from fishing damage for a number of cold-water coral resources. National Marine Sanctuaries and environmental compliance in the management of outer continental shelf natural gas and oil leases by the Minerals Management Service of the U.S. Department of the Interior may provide additional protection for some cold-water corals.

### **Northeast United States**

U.S. waters north of Cape Hatteras contain numerous cold-water hard corals, soft corals and hydrocorals. The major structure-forming corals are primarily octocorals (Paragorgia, Acanthogorgia and Primnoa). Species that depend on a hard base are most abundant in the canyons along the continental slope and on the New England seamount chain (which extends beyond the U.S. EEZ). The distribution and abundance of cold-water corals in this region remains poorly known, and only a few surveys have been conducted. In 2004, the New England and Mid-Atlantic Fishery Management Councils recommended the protection of two submarine canyons with known cold-water coral resources from monkfish bottom-trawling.

### **Southeast United States and Gulf of Mexico**

These waters contain the best-developed deep coral reefs in U.S. waters formed from the stony *Oculina*, *Lophelia* and *Enallopsammia* corals. The status of the *Oculina* reefs, which are only found at a depth of 60-100 m off eastern Florida, have deteriorated since they were documented in the 1960s. The narrow reef area stretches some 167 km along the shelf break about 32 to 68 km offshore. Submersible dives sponsored by NOAA in the 1970s showed large coral reefs rich in shrimp and fish such as groupers, which became a target for commercial and recreational fishery in the following years. This geographically restricted reef area is one of the first known examples of cold-water coral reefs living in close proximity, to warm-water corals, although they are in deeper waters and further offshore.

In 1984, a substantial portion (315 km<sup>2</sup>) of this *Oculina* reef ecosystem became the first cold-water coral MPA in US waters; a decision prompted by the recommendation of the South Atlantic Fishery Management Council. Trawling, dredging and other disruptive activities, such as anchoring, were banned within the *Oculina* Bank Habitat Area of Particular Concern (OHAPC). In 1994, the OHAPC was closed to fishing for snapper and grouper species for 10 years as a precautionary measure. This area, now known as the *Oculina* Experimental Closed Area, was closed to test the effectiveness of a fishery reserve for the restoration of fish stocks. In 2003, the area was extended in order to update the research plan and better evaluate the current results. The OHAPC was enlarged in 2000 to 1,029 km<sup>2</sup> with the prohibition on fishing for snapper and grouper species only applying within the *Oculina* Experimental Closed Area.

Despite considerable efforts to protect the *Oculina* reefs off eastern Florida, recent ROV and submersible surveys show that illegal trawling and fishing activities have reduced much of the reef habitat to coral rubble. Consequently, NOAA recently increased surveillance and enforcement of the OHAPC. However, recently discovered *Oculina* reefs outside the OHAPC are vulnerable to damage caused by legal fishing.

In addition to *Oculina* reefs, deep-water banks of *Lophelia pertusa* and *Enallopsammia profunda* corals occur at depths of 700-850 m along the base of the Florida-Hatteras slope, off the coasts of North and South Carolina, Georgia and Florida. These cold-water reefs are only beginning to be explored, but appear to be the most extensive cold-water reefs in the Northwest Atlantic. The South Atlantic Fishery Management Council is considering new MPAs to protect these coral habitats from fishing damage.

*Lophelia pertusa* and *Madrepora oculata* coral aggregations also occur in the U.S. EEZ along the continental slope of the Gulf of Mexico. Impacts from fishing gear and oil and gas exploration or development are potential threats in these areas.

### United States West Coast, Alaska and Aleutian Islands

Cold-water corals, especially octocorals, are widely distributed along the Pacific continental shelf, continental slope, and seamounts of North America. Much of the available information on the distribution of cold-water corals in this region comes from records of coral bycatch in fisheries. Recent submersible explorations in Alaska have revealed exceptionally rich coral and sponge habitats. Validated information on fishing impacts on coral grounds is available from the Aleutian Islands. U.S. Federal fishery observer data indicate extensive sponge and coral bycatch occurred in the Aleutian Islands fisheries. The North Pacific Fishery Management Council prepares fishery management plans for U.S. EEZ around Alaska, and has protected more than 180,000 km<sup>2</sup> in the Gulf of Alaska from trawling. The Council is currently considering options for additional protection measures for cold-water coral habitats on the continental shelf, Aleutian Islands and Alaskan seamounts.

### United States Insular Pacific

Cold-water corals, especially octocorals, occur in the waters around Hawaii, other U.S. islands and seamounts of the Central and Western Pacific. Trawling has not been permitted in the U.S. EEZ of the Central and Western Pacific since 1983. There are black coral and precious coral beds in Hawaii, where there is a limited, but well-managed, fishery for several species used to make jewellery. Recently, the black coral fishery has been threatened by an invasive soft coral species, *Carijoa riise*, from the Caribbean. The soft coral has been found overgrowing and killing up to 90% of black coral colonies in surveyed areas below 75 m.

## PACIFIC OCEAN AND INDIAN OCEAN

Little is known about the status of cold-water corals in the Pacific and Indian Oceans. The corals are presumably widely dispersed on the many thousands of seamounts, as well as on the continental slopes of islands and continents. However, only a small number of these sites have been visually surveyed, showing that coral density declines below 1,000 to 1,500 m. The density of precious corals in the North Pacific is greatest at 100 to 400 m and 1,000 to 1,500 m, and coral abundance seems to depend directly on the productivity of the overlying waters.

Many seamounts less than 1,500 m below the surface have been commercially exploited for mineral resources and fish, with more than 70 commercial fish species taken off seamounts as well as 20 species of precious corals. Since the mid-1960s, successive waves of fisheries have targeted the extensive coral and fish resources off seamounts in the North and South Pacific, and Atlantic and Indian Oceans. Fishing effort has often been massive: between 1969 to 1975 there were 18,000 trawler days of effort by the former Soviet Union fleet trawling on a few seamounts in the southeast Emperor-northern Hawaiian Ridge system, and more than 100 Japanese and Taiwanese vessels started a second wave of coral fishing on central North Pacific seamounts in 1981.

Seamount fisheries are particularly vulnerable to over-exploitation due to their isolation, and most species taken are often particularly long lived and show infrequent recruitment. These fisheries are characterised by 'boom and bust' cycles. At the end of the 1970s, when the pelagic armorhead (*Pseudopentaceros* spp.) fishery collapsed, seamount fisheries shifted first to the southwest Pacific for orange roughy (*Hoplostethus* spp.) around New Zealand and Tasmania and then to the Indian Ocean, North Atlantic Ridge and the southeast Atlantic off Namibia. Tropical and subtropical seamounts have been exploited for alfonsino (*Beryx* spp.), but the



precise locations of these fisheries are often not recorded, particularly when they occur in international waters (e.g. the central Indian Ocean) or when they involve poaching within the EEZ of another country.

There are few observations of the damage of this fishing on benthic communities, however, coral bycatch from orange roughy fisheries around New Zealand and Tasmania has been substantial, particularly in the early years when 1-15 tons of coral bycatch were taken per trawl. Now photos show that there is virtually no coral cover, living or dead, left on heavily fished seamounts off Tasmania; a marked contrast to un-fished or lightly fished seamounts.

There is usually little overlap in species composition between groups of seamounts; no species have been found in common between seamounts south of Tasmania and those on the Norfolk Ridge or Lord Howe Rise in the northern Tasman Sea and southern Coral Sea. This high degree of endemism greatly increases the risk of extinction of biodiversity by the large-scale removal of bottom fauna from seamounts. Very few of the seamounts in the Pacific and Indian Ocean have been protected, and only a few countries have adopted measures to conserve seamount habitats and ecosystems in their territorial waters.

**Seamounts in the Australian EEZ:** The summits of seamounts south of Tasmania and within the Australian EEZ are rich in the reef-building cold-water coral *Solenosmilia variabilis* that provides a good habitat for a diverse range of other animals, including many fish species. In 1999, the Australian Government declared the Tasmanian Seamounts Marine Reserve under the National Parks and Wildlife Conservation Act (1975). The key objectives of the management plan are:

- To add a representative sample of this unique seamount region to the National Representative System of Marine Protected Areas; and
- To protect the high biodiversity values of the seamount benthic communities from human-induced disturbance.

The reserve has two management zones with different objectives and permissible activities. There is a highly protected zone near the bottom, that is managed to protect the coral reef ecosystems, and where no fishing or petroleum or mineral exploration is permitted. Above this there is a managed resource zone from the ocean surface to 500 m depth, which allows tuna long-line fishing in the surface waters.

**Seamounts in the New Zealand EEZ:** The key goals of the New Zealand Government are to maintain the biodiversity and productive ecosystems on seamounts within their EEZ. The Ministry of Fisheries protected 19 representative seamounts from bottom trawling and dredging under a Seamounts Management Strategy in 2001, and a national strategy has addressed protection of deepwater biodiversity from bottom trawling since September 2004. These seamounts are distributed around the EEZ, including the Chatham Rise, sub-Antarctic waters, and the east and west coasts of the North Island. The protected seamounts vary from the very large Bollons Seamount in the sub-Antarctic, to tiny seamounts on the Chatham Rise. Although little is known about their fauna, it is hoped this precautionary approach will protect representative components of the animals and habitats. None of these seamounts have been fished, except for Morgue, which was included to study re-colonization and regeneration after the fishing stopped.



## **INFORMATION MANAGEMENT AND RESEARCH**

The distribution of cold-water corals and reefs is still poorly known. Information is especially poor in tropical and sub-tropical deep-water areas near developing countries and small island developing states. Most location records are held by individual experts and scientific institutions, or by companies exploring the deep waters for commercial purposes. There is a need to combine this information from the various sources, maintain the data in secure places, and present summary information to all stakeholders to improve conservation and management. However, it is particularly time consuming and expensive to gather these data using the latest deep-sea technology and instruments. Modelling the potential distribution of cold-water coral reefs will focus further research and habitat mapping, especially in the tropical and subtropical areas where direct observations of the reefs are very limited.

The knowledge about the biology of cold-water corals is also poor, with little information on the structure and function of cold-water coral ecosystems. There is also little understanding of the effects of different human activities on these corals and reefs and their capability to regenerate. Furthermore, cold-water coral field research is expensive, and can potentially cause damage to the systems being studied. Therefore, there is a need for good international coordination of marine research programs, so that research efforts can be focused on achieving cost efficiency and minimising damage to the coral habitats.

## **MONITORING AND ASSESSMENT**

Most regulations and measures to protect cold-water coral reefs have only been established recently, and little information exists about their efficacy in achieving conservation objectives. Since many of these areas occur far offshore or in international waters, monitoring, surveillance and enforcement of measures will be expensive and pose special challenges. More regulations and measures are going to be established soon, therefore it is becoming increasingly important to compile and share information about the range of management strategies adopted by various countries and organisations, and to develop monitoring and assessment tools to evaluate and redefine the approaches taken to protect the reefs. This will help guide countries in their efforts to manage cold-water coral reefs, especially those countries with fewer resources for basic research.

Appropriate monitoring is vital for the conservation, protection and sustainable management of ecosystems. The monitoring of remote and deep-water habitats is still challenging and requires the development of methods and equipment which are robust, practicable, flexible and cost efficient, so that they can be customised to local conditions and applied in waters of both developed and developing countries. Monitoring efforts should be able to describe the status of undisturbed reefs, and the state and recovery of damaged reefs, as well as the environmental and socio-economic effects of conservation and management regulations and measures.

In the light of the increasing amount of data and information becoming available from various sources, there is a need to consider establishing and maintaining database facilities. Regular publications on the health and status of cold-water coral reefs are needed, similar to those in place for warm-water tropical reefs. Availability of such information will assist resource managers in coral reef conservation.

## CONCLUSIONS AND RECOMMENDATIONS

Cold-water coral reefs and ecosystems are long-lived and fragile, and particularly vulnerable to physical damage. Impacts of human activities and the signs of deliberate or accidental damage to cold-water coral reefs are evident in almost every survey, regardless of the depth at which the corals occur. Bottom trawl fisheries represent the major threat, with other threats including hydrocarbon and mineral exploration and production, cable and pipeline placement and waste dumping. There are large gaps in our knowledge about these ecosystems, including the distribution and ecological functions. However, these cold-water coral reefs have great ecological and socio-economic importance, and without urgent and precautionary action for their conservation, protection and sustainable management, the goods and services these magnificent reefs may supply could be lost forever. The following recommendations include some from the recent report 'Cold-water Corals: out of sight – no longer out of mind':

- Research into the geographical distribution and the ecological functioning of these ecosystems is urgently needed, especially in the deeper waters of tropical and sub-tropical areas. There is a need to promote targeted research to predict and verify experimental and in-situ observations of the biological functioning, ecological connections and habitat distribution. The study of cold-water coral ecosystems requires considerable international coordination and cooperation, so that information can be easily accessed and shared to make best use of existing resources;
- Monitoring and assessment of cold-water coral reefs and the socio-economic costs and benefits associated with them is necessary for their effective conservation, protection and sustainable management. Most cold-water coral reefs are deep and remote; this provides challenges and requires the development of robust and feasible monitoring methods. The range of management strategies adopted by various countries and organisations should be compiled, and sharing of information, knowledge and lessons learned is critical.
- States with cold-water coral ecosystems should develop effective regulations and measures to conserve, protect and manage these ecosystems sustainably, based on precautionary and adaptive approaches. Cold-water coral reefs should be included within networks of MPAs to be established by 2012, according to the international commitments made at WSSD in Johannesburg in 2002. The effectiveness of existing regulations and measures should be regularly evaluated. Options for the sustainable management, conservation and protection of cold-water coral ecosystems outside of national jurisdiction should be explored and developed under the framework of UNCLOS and CBD.
- Stakeholder involvement is particularly important in the development of regulations and measures. Including the full range of stakeholder concerns and interests will increase the chance of successful and effective implementation of, and compliance with, such regulations and measures. Enforcement of existing regulations should be strengthened.
- There is a continuing need to raise awareness about cold-water coral ecosystems and associated communities. International collaboration is required to include all stakeholders and to disseminate information on the existence, importance and need for research on, and protection of, these ecosystems to scientists, industry, policy makers and the general public.

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## SCIENTISTS' STATEMENT ON PROTECTING THE WORLD'S DEEP-SEA CORAL AND SPONGE ECOSYSTEMS

As marine scientists and conservation biologists, we are profoundly concerned that human activities, particularly bottom trawling, are causing unprecedented damage to the deep-sea coral and sponge communities on continental plateaus and slopes, and on seamounts and mid-ocean ridges.

Shallow-water coral reefs are sometimes called “the rainforests of the sea” for their extraordinary biological diversity, perhaps the highest anywhere on Earth. However, until quite recently, few people - even marine scientists - knew that the majority of coral species live in colder, darker depths, or that some of these form coral reefs and forests similar to those of shallow waters in appearance, species richness and importance to fisheries. Lophelia coral reefs in cold waters of the Northeast Atlantic have over 1,300 species of invertebrates, and over 850 species of macro- and mega-fauna were recently found on seamounts in the Tasman and Coral Seas, as many as in a shallow-water coral reef. Because seamounts are essentially undersea islands, many seamount species are endemic - species that occur nowhere else - and are therefore exceptionally vulnerable to extinction. Moreover, marine scientists have observed large numbers of commercially important but increasingly uncommon groupers and redfish among the sheltering structures of deep-sea coral reefs. Finally, because of their longevity, some deep-sea corals can serve as archives of past climate conditions that are important to understanding global climate change. In short, based on current knowledge, deep-sea coral and sponge communities appear to be as important to the biodiversity of the oceans and the sustainability of fisheries as their analogues in shallow tropical seas.

In recent years scientists have discovered deep-sea corals and/or coral reefs in Japan, Tasmania, New Zealand, Alaska, California, Nova Scotia, Maine, North Carolina, Florida, Colombia, Brazil, Norway, Sweden, UK, Ireland and Mauritania. Because research submarines and remotely operated vehicles suitable for studying the deep sea are few and expensive to operate, scientific investigation of these remarkable communities is in its very early stages. But it is increasingly clear that deep-sea corals usually inhabit places where natural disturbance is rare, and where growth and reproduction appear to be exceedingly slow. Deep-sea corals and sponges may live for centuries, making them and the myriad species that depend on them extremely slow to recover from disturbance. Unfortunately, just as scientists have begun to understand the diversity, importance and vulnerability of deep-sea coral forests and reefs, humans have developed technologies that profoundly disturb them. There is reason for concern about deep-sea oil and gas development, deep-sea mining and global warming, but, at present, the greatest human threat to coral and sponge communities is commercial fishing, especially bottom trawling. Trawlers are vessels that drag large, heavily weighted nets across the seafloor to catch fishes and shrimps. Scientific studies around the world have shown that trawling is devastating to corals and sponges. As trawlers become more technologically sophisticated, and as fishes disappear from shallower areas, trawling is increasingly occurring at depths exceeding 1,000 meters.

It is not too late to save most of the world's deep-sea coral and sponge ecosystems. We commend nations including Australia, New Zealand, Canada and Norway, which have already taken initial steps towards protecting some coral and sponge ecosystems under their jurisdiction. We urge the United Nations and appropriate international bodies to establish a moratorium on bottom trawling on the High Seas. Similarly, we urge individual nations and states to ban bottom trawling to protect deep-sea ecosystems wherever coral forests and reefs are known to occur within their Exclusive Economic Zones. We urge them to prohibit roller and rockhopper trawls and any similar technologies that allow fishermen to trawl on the rough bottoms where deep-sea coral and sponge communities are most likely to occur. We urge them to support research and mapping of vulnerable deep-sea coral and sponge communities. And we urge them to establish effective, representative networks of marine protected areas that include deep-sea coral and sponge communities.

Signed by 1,136 scientists; source [www.mcabi.org/DSC\\_statement/sign.htm](http://www.mcabi.org/DSC_statement/sign.htm)

### **RECOMMENDED WEBSITES**

[www.unep-wcmc.org/press/cold\\_water\\_coral\\_reefs/](http://www.unep-wcmc.org/press/cold_water_coral_reefs/);  
[www.coris.noaa.gov/about/deep/deep.htm](http://www.coris.noaa.gov/about/deep/deep.htm);  
[www.ngo.grida.no/wwfneap/Publication/pubframe.htm](http://www.ngo.grida.no/wwfneap/Publication/pubframe.htm);  
[www.iucn.org/themes/marine/pubs/pubs.htm](http://www.iucn.org/themes/marine/pubs/pubs.htm);  
[www.highseasconservation.org/publications.cfm](http://www.highseasconservation.org/publications.cfm);  
[www.imr.no/coral](http://www.imr.no/coral); [www.ecoserve.ie/projects/coral/index.htm](http://www.ecoserve.ie/projects/coral/index.htm); [www.sams.ac.uk/sams/projects/benthic/lophelia.htm](http://www.sams.ac.uk/sams/projects/benthic/lophelia.htm)



## 4. STATUS OF CORAL REEFS IN THE RED SEA AND GULF OF ADEN IN 2004

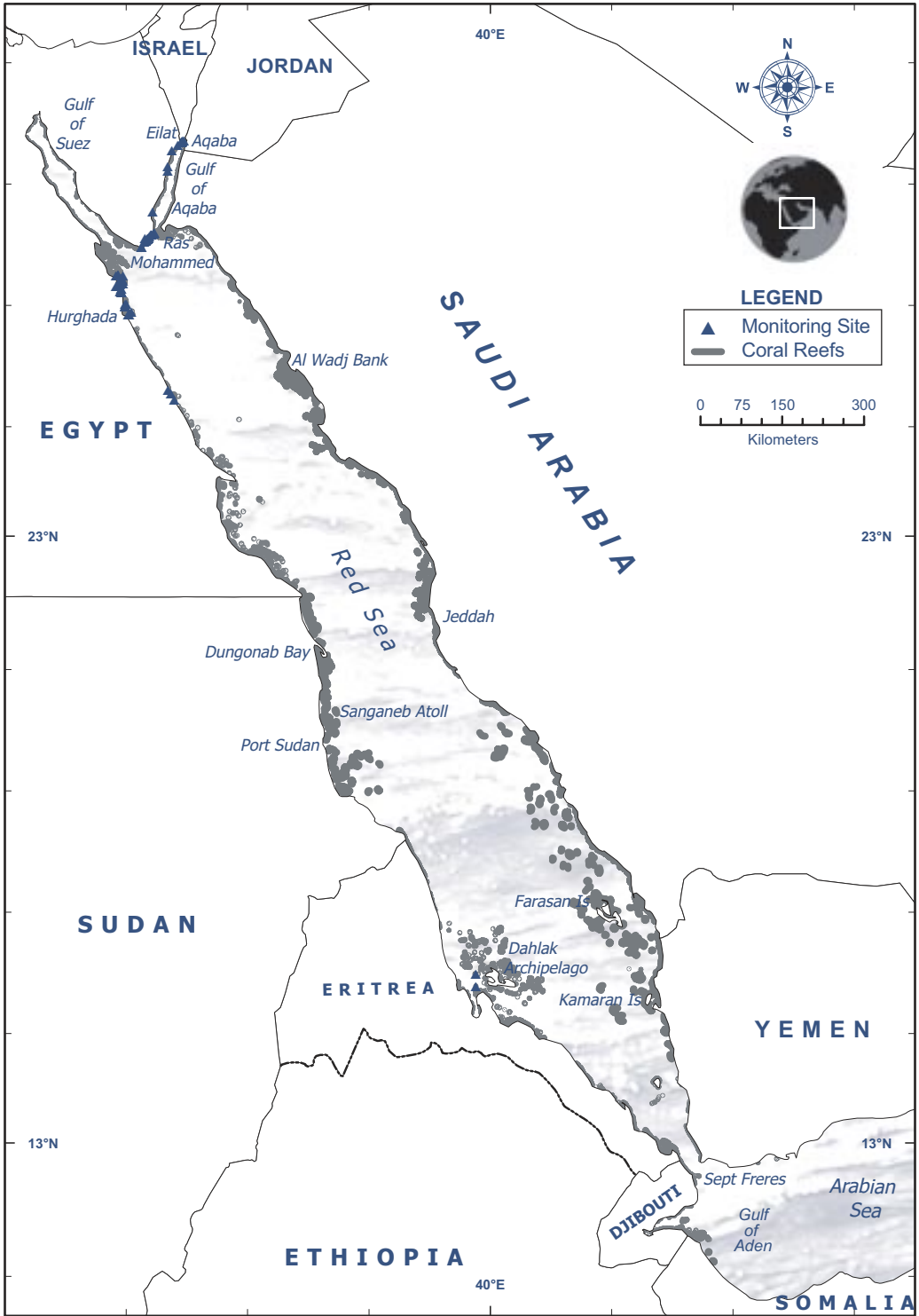
MOHAMMED KOTB, MALEK ABDULAZIZ, ZAHER AL-AGWAN, KHALID AL-SHAIKH, HATEM AL-YAMI, ABDELELAH BANAJAH, LYNDON DEVANTIER, MICHAEL EISINGER, MOHAMMED ELTAYEB, MOSHIRA HASSAN, GEORG HEISS, STEFFAN HOWE, JERRY KEMP, REBECCA KLAUS, FAREED KRUPP, NABIL MOHAMED, TONY ROUPHAEL, JOHN TURNER AND UWE ZAJONZ

### ABSTRACT

The status of coral reefs and coral communities in the Red Sea and Gulf of Aden is generally good, with coral cover averaging 20-50%. This includes decreases and increases in live coral cover since 2002. The 1998 bleaching event caused major damage on parts of the southern Red Sea and Gulf of Aden, but caused no damage in the northern Red Sea; in some areas the recovery has been strong, and weak in others. Recent outbreaks of the crown-of-thorns starfish (COTS) have occurred in Egypt, Saudi Arabia, Djibouti and western Somalia, along with some local bleaching. Threats to coral reefs differ in the region, but are increasing with the increasing rate of coastal development. The major local threats include land fills, dredging, sedimentation, sewage discharge and effluents from desalination plants, mostly around towns, cities and tourist development sites. There is local reef damage around major tourism areas, caused by people and boat anchors, along with other threats. Fish populations are declining in some areas, because of increased demand for and fishing pressure on food and ornamental species. Destructive fishing practices such as trawling in fragile habitats is increasing. There has been an influx of illegal fishing vessels seeking to meet demands of the export market and more affluent and growing populations locally. The other major threats are from pollution and shipping accidents, and future bleaching. Monitoring these reefs is becoming increasingly important, as climate change and warmer waters near the limits for coral growth.

Most countries have enacted national legislation for coral reef conservation, and signed multinational agreements with assistance from the Regional Organisation for the Conservation of the Environment of the Red Sea and Gulf of Aden (PERSGA). However, these laws are either poorly implemented or enforced and often are ignored completely. The main need is to enforce national and international laws, develop public awareness programs and adopt sustainable management strategies. This will require long-term strategies for capacity building. PERSGA developed a Strategic Action Program in 1998 and a Regional Action Plan in 2003 for reef





conservation. The plan aims to reduce impacts with: Integrated Coastal Management; Education and Awareness; Marine Protected Areas; Ecologically Sustainable Reef Fisheries; Shipping and Marine Pollution control; and Research, Monitoring and Economic Valuation. Several major new MPAs are being developed in Djibouti, Eritrea, Saudi Arabia, Sudan and Yemen. Management of existing MPAs in a number of countries, including Egypt and Yemen, has improved, with support from the Global Environment Facility and bilateral donors. A UNDP/GEF Coastal, Marine and Island Biodiversity Project is starting in Eritrea.

**100 years ago:** Following the opening of the Suez Canal in 1869, the region was a major international shipping route with occasional shipwrecks and related oil spills. There were invasions of alien species but damage from human activities was minimal. There were some artisanal fishers but fishing pressure was low and fish stocks were largely unexploited. The reefs were predominantly healthy.

**In 1994:** Most reefs were in good condition, with sustainable levels of fishing and low levels of human damage, except near towns, cities and tourist sites. Some reefs were affected by COTS outbreaks in the 1970s, and bleaching in the early 1990s.

**In 2004:** Urban growth, coastal land reclamation and fisheries are expanding, and COTS outbreaks are continuing. Tourism continues to expand in some countries, but not others. There has been strong recovery of some reefs badly damaged by the 1998 bleaching event, but others have shown no recovery. There has been some success in establishing MPAs, but there is no effective regional MPA network, and most of the declared MPAs have ineffective management.

**Predictions for 2014:** Pressures will increase from: major development for mass tourism and industrialisation; over-exploitation and destructive fishing in poorly managed fisheries; COTS outbreaks; and bleaching events. Over-exploitation of fish throughout much of the region will pose a more serious threat, unless regulations are strengthened and enforcement improved. Further large-scale bleaching events, like that of 1998, may prove catastrophic to stressed coral reefs in the Gulf of Aden and southern Red Sea. These impacts will probably lead to decreases in the health and extent of reefs, reduce their renewable goods and services, and lower natural recovery. However many reefs in the region will remain healthy, particularly those remote from development or with strong currents or cool upwellings.

## INTRODUCTION

This report summarises recent research and management in countries of the Red Sea and Gulf of Aden, including the Arab League nations of Djibouti, Egypt, Jordan, Saudi Arabia, Somalia (north coast), Sudan, and Yemen, and the non-affiliated Eritrea.

## GEOGRAPHICAL SETTING AND REEF COVERAGE

The Red Sea is 2,270 km long from 30°N in the Gulf of Suez to 13°N at Bab el-Mandab where it joins the Gulf of Aden. It is a maximum of 350 km wide and 2,920 m deep and surrounded by extremely arid coastlines. The southern entrance at the Straits of Perim is only 130 m deep, which restricts water exchange between the Red Sea and the Gulf of Aden. The land surrounding the Red Sea is hot and dry with minimal freshwater inflows, and high rates of evaporation. The input of surface waters from the Gulf of Aden must compensate for evaporation losses. As a result the salinity varies along the Red Sea from 36.5ppt at the southern entrance, to more than 41ppt

in the northern Gulf of Aqaba in summer. Water temperatures and nutrient concentrations decrease in surface waters towards the northern end, where the water is generally clearer.

All major reef types occur in the region, including barrier reefs and extensive fringing reefs and patch reefs bordering the coasts and islands of Djibouti, Egypt, Eritrea, Jordan, Saudi Arabia, Sudan, and Yemen. There is one atoll, Sanganeb, and pinnacle reefs in the Central and Southern Red Sea. Coral reef development is limited by cold seasonal upwelling in the Gulf of Aden off Djibouti, Northern Somalia and Yemen. Many fringing reefs in clearer water have high coral cover close inshore and around islands away from the shore.

The Red Sea has high biodiversity, including approximately 300 reef-building coral species and over 1400 fish species. The biological diversity of other animals and plants associated with coral reefs is also high. There are many endemic species making this region a globally significant repository of biodiversity. The reefs and associated seagrass beds also support endangered turtles and dugong.

Coral distribution is patchy and true reefs are generally not well developed in the Gulf of Aden, although there are mixed coral-dominated communities with moderately diverse hard and soft coral fauna of some 150 species, plus many sponges and macro-algae. The Socotra Archipelago at the entrance to the Gulf of Aden has diverse reef communities, including 250 reef-building coral species, more than 700 fish species and 120 species of algae. More details are summarised in Chapter 2 in 'Status of the Coral Reefs of the World: 2002' and the 'World Atlas of Coral Reefs'.

## **REEF STATUS AND MANAGEMENT**

### **Regional Level**

Reef health is considered to be predominantly good, with 20% – 50% live coral cover at many locations, a generally positive ratio of live to dead coral cover, and high diversity and healthy stocks of key indicator species. The major regional stress during the last decade was coral bleaching in 1998, particularly in the southern Red Sea and Gulf of Aden; although this was highly patchy not affecting Egypt, northern Saudi Arabia, and Jordan. COTS outbreaks have also occurred in some countries. Progress has been made in coral reef monitoring, and many surveys are conducted using GCRMN – Reef Check protocols, consistent with recommendations of the 'Standard Survey Methods for Key Habitats and Key Species in the Red Sea and Gulf of Aden'. However, there is a lack of capacity to design, implement and support monitoring and management programs. Much more capacity is needed and major challenges remain to achieve effective coordination and implementation of national surveys, monitoring activities and reporting. Little new information has been received since 2002 for several countries.

Reef fish stocks are coming under increasing pressure, with rising national and international demand for food and ornamental aquarium species. Increasing activities in some parts contravene CITES regulations with the export of endangered turtles and of corals. Edible sea cucumbers are currently fished in most countries of the Red Sea for export to SE Asia. This industry is new to the region and harvesting is increasing rapidly. There is poor enforcement of existing regulations, and often conflicting policies and objectives about fisheries among different government departments. Moreover there is insufficient data to develop sound management policy. Aquaculture development is increasing in the region, and large shrimp farms are being developed in many countries, including Saudi Arabia, Sudan and Eritrea.

A Regional Action Plan for the Conservation of Reefs in the Red Sea and Gulf of Aden was developed in 2003, with 6 major components aimed at ameliorating predicted damage to reefs:

- i. **Integrated coastal management (ICM):** Implement ICM in all participating countries, supported by appropriate legislation, land use planning, participatory approaches, socio-economic and environmental impact assessment, monitoring and enforcement. Poorly planned and regulated coastal developments for tourism and urban expansion have caused the greatest local impacts and pose significant future threats in most countries.
- ii. **Marine protected areas (MPAs):** Establish a biologically interconnected network of MPAs, deemed crucial to the long-term maintenance of reef ecosystems and viability of populations of endemic, rare, threatened or endangered and harvested species. Most countries have already taken important steps toward developing MPAs, although considerable differences in management capacity exist, and capacity-building remains a priority. A series of demonstration MPA sites throughout the region have been proposed and/or established and site specific management plans are now written for some areas. The list of proposed demonstration sites includes (from north to south): Aqaba Marine National Park (Jordan); Ras Mohammed National Park (Egypt); Giftun Islands and Straits of Gubal (Egypt); Dungonab Bay and Mukawwar Island (Sudan); Sanganeb Atoll (Sudan); Farasan Islands Marine Park (Saudi Arabia); Iles des Sept Freres (Djibouti); Aibat and Saad ad-Din (NE Somalia); Belhaf – Bir Ali (Yemen); and Socotra Group of Islands (Yemen). Other MPAs will join these sites as capacity develops.
- iii. **Ecologically sustainable reef fisheries:** Implement accurate stock assessment and monitoring, effective regulation of fishing effort (e.g. through licensing) and ‘no-take’ zones in MPAs, with seasonal closures to protect spawning stocks, surveillance and enforcement. Recent examples include establishment of ‘no-take’ zones in MPAs in Egypt, Saudi Arabia, Sudan and Yemen. Reef fisheries, and other demersal fisheries which deliberately or inadvertently affect reefs, are expanding in most countries as national and international demand continues to grow, other than some MPAs, this growth remains largely unregulated or enforced.
- iv. **Shipping and marine pollution:** Implement obligations under regional and international conventions, including adoption of Port State Control, improved navigation systems and oil spill response capacities, surveillance and enforcement. The region is one of the major global thoroughfares for international maritime traffic, placing reefs at high risk of groundings, spills, pollution and introduction of alien species in ballast waters.
- v. **Research, monitoring and economic valuation:** Implement standard methods of biophysical and socio-economic survey and monitoring, including GCRMN – Reef Check protocols, to support ICM, MPAs, fisheries and shipping components. Biophysical monitoring is continuing in key locations, including in Egypt and the Socotra Islands (Yemen), and currently being established in various coastal and island locations of the Yemen Red Sea and NE Gulf of Aden.
- vi. **Education and awareness:** Increase government and public awareness of the various values and renewable goods and services of reefs through networks, the mass media, schools, universities and local communities. Recent initiatives for capacity-building include assessments of training and equipment needs and development of training program outlines in public awareness and eco-tourism in Djibouti, Egypt, Saudi Arabia, Northern Somalia, Sudan and Yemen.

Eritrea is not included in PERSGA, and is implementing its own plans through a UNDP-GEF Project based in Massawa (see below).

Three areas were recently recommended with the highest global priority for inclusion on the World Heritage Register for their outstanding tropical marine biodiversity: parts of the northern Red Sea and Gulf of Aqaba (including areas of Saudi Arabia and Egypt); parts of the Southern Red Sea 'Complex' (including areas of Saudi Arabia, Yemen, Djibouti, Eritrea); and the Socotra Archipelago (Yemen). Socotra is a UNESCO 'Man and Biosphere Reserve'. Parts of Southern Egypt, central Sudan and the Gulf of Aden coast of Yemen (Bir Ali area) were also recommended for World Heritage listing.

The following information has been summarised from the 'Country Reports' produced by PERSGA in the framework of the Strategic Action Program for the Red Sea and Gulf of Aden, and updated from various sources, including survey and monitoring data and management plans from 2002 - 2004.

### **Djibouti**

There is discontinuous coral growth along the 370 km coastline of Djibouti with the total coral reef area being 12 km<sup>2</sup>. There are fringing reefs around the Sept Frères Island group, within the Gulf of Tadjoura (a narrow 800 m deep trench), and around the vast fossil reef plateau of the Isles de Maskali and Moucha, at the entrance to the gulf north of Djibouti town. Corals grow between 1 m and 45 m depth, but the relatively high turbidity limits coral growth to the upper 15 – 25 m. These reefs vary in status, from very poor to good, with coral cover often well over 50% and up to 90% in the best areas. In the Gulf of Tadjoura, coral cover ranged from 12% south of Maskali to over 60% off Sable Blanc with an average of 36%. Cover has not changed much since surveys in 2000, however, several sites off Maskali Island were deteriorating. Some coral reefs are completely covered in algae, and reef flats covered in rubble from eroding table corals. These losses have been caused by the combination of coral bleaching and large numbers of COTS.

There is minimal coral disease recorded, mainly white band disease and black band disease, although coral eating snails *Drupella* sp. and *Coralliophila* sp. were present. There have been COTS outbreaks in the Gulf of Tadjourah and Isles des Sept Frères during 1998 – 2000, but no signs of recent bleaching events. Coral mortality at Iles des Sept Frères is attributed to the 1998 bleaching event. Coral cover in 2002 was: up to 90% at Kadda Dabali; 32-66% at Grande Ile, Tolka Ile Basse; 44% at Horod Le Rhale Ile de l'Est; 47% (range 13 - 64%) at Rhounda Komaytoug Ile du Sud, up to 60% at Hamra Ile de l'Ouest; and 25% (range 10 - 55%) at Khor Angar.

Djibouti's reefs are under threat from domestic tourism, sewage discharges, shipping and associated spills and pollution, with pressure particularly high around the capital city. Shipping is an important commercial sector in Djibouti, which is the major harbour for Ethiopia. Anchor, boating and tourism damage is increasing, with little increase in environmental awareness. International tourism is just developing and damage is limited. The low level of fishing is mostly for subsistence and there is limited exploitation of tropical fish for live export, but aquarium fish collecting is increasing. Djibouti is developing several MPAs including Moucha, Maskali ('Moucha Territorial Park' and the 'Integral Park of South Maskali) and Sept Frères/Ras Siyyan and Godoria. Maskali and nearby Moucha Island, in the Gulf of Tadjourah, were included in the first MPA declared in the Red Sea and Gulf of Aden in the early 1970s, however there is no effective

management. In 2004, PERSCA published a management plan for the Isles des Sept Frères/Ras Siyyan and Godoria Marine Protected Area, but management has not been implemented.

### **Egypt**

There are a wide range of reefs including mainland and island fringing reefs, coral pinnacles and patch reefs along the 1800 km Egyptian Red Sea coast. These reefs sustain major international tourism operations, semi-subsistence harvesting, fishing and aquaculture. Tourism contributes significantly to the economy through tourist charges and spending. Coral reefs range widely in condition and cover, with up to 85% living coral cover at the best sites. Coral cover was significantly higher in the Red Sea than in the Gulf of Aqaba, ranging from 16-67% at 5 m depth, with an average of 45% in the Red Sea, and 35% in the Gulf of Aqaba. The 1998 global bleaching event had little effect in Egypt, but coral cover in some areas has declined by more than 30% due to coastal development, COTS outbreaks, illegal anchoring, scuba diving, snorkelling and reef walking. Coral cover at 2 sites in the Gulf of Aqaba decreased from 37% to 13% between 1997 and 2002, most probably due to COTS outbreaks.

Tourism activity is intense with some reef sites receiving over 75,000 divers per year. Commercial fishing is widespread and remains largely unregulated. The consequences of fishing are unknown except for the reduced biomass and mean length of target species. Butterflyfish and sweetlips decreased markedly in abundance in the Gulf of Aqaba and Red Sea from 1997 to 2002. The abundance of groupers and parrotfish remained stable in the Gulf of Aqaba, but decreased in the Red Sea. There is better enforcement of no-take zones and fishing prohibitions in South Sinai than in the Red Sea.

Reefs are threatened by oil pollution and solid waste discharged from vessels. Most human damage is around major tourist development sites (e.g. Hurghada, Safaga, Sharm El Sheikh), at reefs lacking mooring buoys and where tourist boats used to anchor on the leeward sides of reefs. Inter-tidal reefs have been damaged by inappropriate development. Some hotels were built on reclaimed land, although most reef flat disturbance has ceased since the laws have been enforced. Dredging for harbour and artificial lagoon construction for hotels, although illegal, continues. Seagrass beds are particularly vulnerable to disturbance by anchors and chains, while mangroves have been damaged by camel grazing and wood harvesting.

The Egyptian Environmental Affairs Agency (EEAA), the Egyptian Environmental Policy Programs (EEPP), and international donors, are strengthening protection of the reefs and other marine habitats. The Wadi El Gemal Hamata Protected Area (PA) was declared in 2003 to protect coral reefs, mangroves, seagrass meadows and terrestrial habitats south of Marsa Alam. A management plan was completed and a ranger station established at its northern boundary. This MPA complements those on the Sinai Peninsula and the Red Sea islands off Hurghada. More than 100 moorings have been placed at high use reefs between Hurghada and Ras Banas since 2002, and the number of EEAA rangers has doubled. The EEPP recently reviewed Egypt's environmental impact assessment procedures, developed environmental awareness guidelines for tourists and completed a strategic conservation plan for the Red Sea between Marsa Alam and Ras Banas. They are attempting to control the type and quality of tourism development, to encourage ecotourism and to increase public awareness of the importance of environmental protection. Several NGOs are active in the region, and the cooperation between the Provinces, the EEAA and the NGOs has steadily improved. A snorkelling and diving tax was recently imposed by the Red Sea Governorate, with a substantial proportion allocated for environmental protection.



The legal framework for the protection of coral reefs is excellent and is implemented in several areas. There is, however, an urgent need for better enforcement and improvements in tourism developments to cope with the increasing pressures, if the coral reefs are to continue to provide income for the country. Important research on coral reefs by local and international scientists continues to be fostered and is assisting MPA managers develop no-take zones, control Bedouin fishing, and limit diving and reef walking.

### **Jordan**

The coral reefs on the short coastline (27 km) in the northern Gulf of Aqaba are in fairly good condition, with up to 80% living coral cover at the best sites. These cooler water reefs in the northern Gulf of Aqaba were not affected by the 1998 warming, however, the pressures from urban, industrial, port, and tourism developments are higher than anywhere else in the region. These pressures result in visible deterioration of coral reefs. Other threats include pollution and shipping, especially phosphate loading, COTS outbreaks and diseases from aquaculture. The Aqaba Coral Reef Protected Area at the Marine Station is the only MPA. Jordan recently revised its legal and regulatory framework, and implemented other measures to conserve the coral reefs, including establishing artificial reefs for divers.

### **Saudi Arabia**

The coral reefs along the 1800 km Red Sea coastline are generally in good condition, with high living coral cover, often exceeding 50%, and healthy stocks of key fish and invertebrate species (except near major cities). Few areas have been surveyed, but the best reefs in 2002, were on the Wajh Bank (average 40% cover at 5 m). Jeddah reefs had 20% cover at 5 m, and the reefs off Farasan Island had 28% at 5 m. Jeddah reefs are influenced by the growing city of 2.2 million people and problems of urban and industrial development including pollution, domestic and industrial sewage dumping, construction, dredging for the construction of marinas, siltation and effluents from desalination plants. A further problem is the increase in local and foreign tourism, boating and diving, and their direct and indirect impacts on the coral reefs. By comparison, the regions of Wajh and Farasan Islands have relatively low human impacts.

Fishing pressure is low to medium in most Saudi Arabian waters, however, it is high in the more remote areas, which are not as well patrolled by the coast guard. Destructive fishing methods are sometimes used to drive fish into the nets at these remote sites. Spear-fishing is illegal in Saudi Arabia, although it is often carried out with the use of scuba, and this may explain the lack of large groupers and other target species in some areas, particularly around towns. There is also some collecting of ornamental reef fishes for the aquarium trade.

The major recent disturbance was the bleaching in 1998, which resulted in localised losses of coral cover and diversity on some reefs, particularly in the south. Damage was patchy elsewhere, and most northern reefs were virtually unaffected. Isolated COTS outbreaks have occurred, but most northern reefs remain in good condition. Recent management initiatives by the National Commission for Wildlife Conservation and Development include the designation of the Wajh Bank and the Gulf of Aqaba as MPAs and the development of master and management plans for these areas.

The proposed Ra's Suwayhil Protected Area has outstanding biological diversity and incorporates nearly 80% of the eastern coastline of the Gulf of Aqaba. Most of the coastline and hinterland remains in a near natural state with no urban and industrial development. The proposed Ra's



Qisbah Marine Protected Area, to the east of the Strait of Tiran, has coral reefs, seagrass beds, intertidal sand flats, and has large densities of dugong. New species of hard corals from the area have been described recently, and there is little commercial and recreational fishing. The Wajh Bank also has healthy diverse reefs, large seagrass beds, and probably the largest population of dugong in the eastern Red Sea. These northern parks will complement those of Egypt and Jordan, and conserve a significant portion of the northern Red Sea coral reefs in MPAs, while further south, the Farasan Islands MPA, will complement those proposed by Sudan, Yemen and Eritrea.

### **Somalia (Gulf of Aden coast)**

There is 1,300 km of coastline on the Gulf of Aden from Ras Casey to the border of Djibouti, with large shallow sandy areas and a few seagrass beds. Coral growth is limited because of a lack of suitable bottom substrates and unfavourable currents. A seasonal upwelling in the Gulf of Aden encourages the growth of macro-algae on most hard substrates on northern Somalia. Corals grow in sheltered bays, but there are few true reefs. However there are extensive areas of coral-dominated communities. The largest and most diverse communities occur near Saad ad-Din Island, and near Karin, in the Maydh area, between Buruc and Bosaso and west of Xabo. Elsewhere there are isolated coral colonies and small coral patches. Coral species diversity is comparatively low and large areas are covered by one species of coral, sometimes with live coral cover of 80%.

These shallow water coral communities and associated reef fish are in near original condition, with minimal damage from recent bleaching events. Reef fisheries are minimal, except near the border area with Djibouti, however uncontrolled lobster fishing is a growing concern along the entire coast. Sharks, lobsters, and more recently sea cucumbers have been heavily harvested along this remote coastline. There was a COTS outbreak in an unknown proportion of reefs in western Somalia in the late 1990s resulting in considerable loss of living corals. Near Djibouti there is a trade in corals, other marine curios and turtle meat for sale in Djibouti. The fishers from Somalia, Djibouti and Yemen operate without any constraints, fisheries management, or enforcement. There are virtually no stresses from the land as the area is sparsely populated, and there is almost no central government presence in the area (Puntland and Somaliland).

The Aibat, Saad ad-Din and Saba Wanak Islands near Saylac were recently surveyed by PERSGA, and the area was declared as Somaliland's first MPA in 2003. The following year Somaliland declared several other MPAs including Daloh Forest Reserve and Maydh Island, a seabird breeding site of international significance. There are no management plans.

The main threats are uncontrolled fisheries, and the international shipping traffic in the Gulf of Aden. Somalia has limited ability to implement legislation and meet national and international obligations. There is a severe lack of effective institutions, funding and trained staff.

### **Sudan**

The 750 km Sudanese coast has fringing and barrier reefs and the oceanic Sanganeb Atoll, which is an MPA of global importance. The reefs range in condition from some sites with more than 70% live coral cover to 15% in other areas. In 2002, the average live coral cover was 44% at 5 m and 34% at 10m (range 15% and 57%). The populations of some key indicator fish groups were average to low compared to the other regions of the Red Sea in 2002, although size of fish was generally larger.

The coral reefs in Dungonab Bay, Sanganeb Atoll, Wingate Reef, Shaab Rumi and Suakin are well studied as they are important for tourism, and Donganab Bay and Sanganeb Atoll have been declared as MPAs with management plans that have not been implemented. The reefs near Port Sudan and Port Basheir are also monitored to assess the damage from industrial activity. Corals are widespread and generally healthy inside Dungonab Bay, and outside the Bay there are extensive fringing and patch reefs, and barrier reefs to more than 30 km offshore. Sanganeb, about 30 km from Port Sudan, is the only atoll in the Red Sea, although it is small at 6.5 km by 1.5 km. Coral cover on the back reef and reef flat varies from 10-30%, while on the outer reef wall cover is 40-70% before a vertical drop to a debris slope. Fringing reefs near Port Basheir remain healthy with 35% cover in the back reef, 51% on the flat and 48% on the slope. Corals at Towartit Reef are less diverse than at Basheir and have lower cover (27% in 2002).

Damage from the 1998 bleaching event is still evident along the coast of Sudan. Corals in the Dongonab Bay showed patchy mortality; in some areas it was 90% from 0 – 15m depth, while other areas were almost entirely unaffected. Coral recovery has been patchy: some areas show high levels of recruitment and growth; but many others show no recovery. The offshore reefs were barely affected in 1998, and remain in very good condition (e.g. Merlot Reef, Abington, Sanganeb Atoll and Shaab Rumi). Outbreaks of COTS caused extensive damage to corals in the 1970s and 1980s, particularly inside Dungonab Bay, but in 2002-03, there were few COTS and minimal coral disease. Similarly, damage by *Drupella* is slight on these reefs.

Construction of an oil pipeline, refinery and marine terminal at Port Bashair, 24 km south of Port Sudan, has increased shipping traffic. These ships have to navigate through breaks in the fringing reefs which poses an accident risk to reefs. Coastal and urban development at Suakin Harbour and north of Port Sudan has damaged the corals, especially as a result of increased sedimentation; 2 km<sup>2</sup> of reef was reclaimed near Port Sudan. Shrimp farms, salt pans, and industrial development around Port Sudan have the potential to damage nearshore reefs. Tourism threats are mainly from boat anchors and breakage by divers, but this is not a serious problem, because there are few tourists. Tourism is growing in Sudan and some early regulation may reduce the type of damage that has occurred elsewhere in the Red Sea. There is low public and government awareness of the need for coral reef conservation, and enforcement of the legal framework is poor.

### **Yemen**

The coastline of Yemen is 2,200 km long, with two thirds in the Gulf of Aden. The Red Sea and Gulf of Aden are markedly different environments and the reef types reflect these differences. The Red Sea coral reefs are mainly coastal and island fringing reefs, with some patch reefs and coral pinnacles; the reefs cover approximately 25% of the coastline. Reefs fringe the limestone islands (e.g. the Kamaran group or the southern Farasans), and the volcanic oceanic islands in clearer water (e.g. the Hunaish, Zuqar and Zubairy groups). There are more than 100 islands in the Yemen Red Sea and only a few have been assessed. Coral growth is generally reduced due to the shallow muddy nature of the shelf; unlike the central and northern Red Sea. There are strong seasonal southerly winds, which stir up the sediments, reduce water visibility and stress the corals. In addition, these shallow waters experience comparatively high water temperatures which further stresses the corals. The reefs are more like reef flats without true crests and slopes. The condition of Yemen Red Sea reefs varies widely. Many were badly damaged in the 1990s by bleaching, COTS outbreaks and trawling, with coral cover losses of up to 90%.

Living coral cover averaged 53% in 2002, with a maximum of 70%. Monitoring of 10 Red Sea sites in 2004 showed a range of healthy live coral cover from 28% to 63%. In other areas, coral cover ranged from 5% to 85% at sites with mixed macro-algae and coral communities. There has been good recovery since 1998, with higher coral cover and species diversity around the Tigfash and Kamaran island reefs in 2004, e.g. at Uqban Kebir island in 1998 there was 43% coral cover at 4 m, and 52% with a doubling of *Acropora* spp. cover in 2004. At Uqban Seghir island, there was extensive mortality around 1998, but in 2004, cover was more than 60%, dominated by *Stylophora* spp. There was still evidence of damage from the 1998 bleaching and COTS and *Drupella* outbreaks at some sites, with large piles of rubble. COTS have re-occurred in high numbers in some areas of the Hunaish Islands in 2004.

Information about coral communities along the Gulf of Aden coast is still sparse. Coral growth is limited by cold-water up-welling during the summer SW monsoons. Thus coral distribution is patchy and the reefs are not well developed, e.g. fringing reefs cover only 5% of the coast. The coral communities also contain large populations of soft corals, sponges and macro-algae, which are diverse and abundant. There are important seagrass areas and biodiversity 'hotspots' near Bir Ali-Belhaf. Hard coral cover previously ranged from 15% in Mukalla to 69% in Belhaf, however this declined dramatically after the 1998 bleaching event. Many areas in the north-eastern Gulf of Aden suffered particularly badly in 1998 with coral mortality of almost 100% in monospecific coral communities. There are few signs of recovery.

The Socotra Group of Islands at the entrance of the Gulf of Aden have rich marine biodiversity and many endemic species. These islands are biogeographic 'crossroads' between the adjacent larger regions. This high biodiversity was the reason the islands were high priority targets for MPAs in 1998-2000 as part of the UNDP-GEF 'Socotra Biodiversity Project'. They are studied well now, with 250 hard coral species, over 120 species of macro-algae, and 730 species of reef fishes. Coral growth on Socotra is affected by cool water upwelling during the south-west summer monsoons, and corals form small, discrete communities, rather than true reef structures. The corals were affected by the 1998 bleaching event, but there has been considerable recovery of surviving corals and new recruits, such that average coral cover is around 30% (Box p 148).

Artisanal fishing is the main source of income for many coastal people on the coasts of Yemen, with high fishing effort that is beyond sustainable levels for many target species, particularly in the Red Sea. The abundance of some of these species has steadily declined; the export sea cucumber fishery has expanded rapidly, and industrial and artisanal trawlers for cuttlefish, shrimp and fish are damaging the reefs. Destructive methods are used to collect aquarium fish around the Kamaran Island Group. Ship groundings have caused some damage. A ship smashed 1,500 m of reef on Zugar Island in 2001; and another in 2004 caused 2,350 m of damage to the coral reef in Mayun (Perim) Island. No cleanup or restoration was carried out and anti-fouling paints probably still remain on the reefs. Tourism has declined recently.

There have been some major management initiatives, including the continuing MPA program on the Socotra Islands (UNDP with national and multilateral support), implementing a reef monitoring program in the Red Sea, and MPA planning along the Red Sea (UNDP-GEF) and Gulf of Aden coasts (Belhaf – Burum and Sharma – Jethmun areas; World Bank-GEF). Integrated Coastal Management and Sustainable Fisheries projects are currently being drafted for both the Gulf of Aden and Red Sea coasts by various agencies and are expected to improve

### MONITORING CORAL RECOVERY ON SOCOTRA, YEMEN AFTER THE 1998 BLEACHING EVENT

There was patchy coral mortality during the 1998 bleaching event around the Socotra Islands, Gulf of Aden, Yemen. Some sites, particularly on the main Island of Socotra, were badly affected, with more than half the coral cover lost, while other sites on the outer islands were barely affected. These islands and the marine communities were designated as protected areas, and a long-term coral monitoring program was established, as outlined in Status of Coral Reefs of the World: 2000. Recent monitoring is showing that average coral cover around Socotra Island increased from 25% in 2000 to 32% in 2001, and remained steady at 31% in 2003. There were some coral losses at one shallow site near the seaport. Hard coral cover increased at 5 of the 6 monitoring sites, indicating considerable recovery of the Socotra corals damaged by bleaching in 1998. There was some localised bleaching at the seaport between 2001 and 2003 with a major loss of mostly branching *Acropora*, probably due to elevated sea surface temperatures in May 2001, and water pollution from development of the port and a road. There was no sign of damage from 1998 on the outer islands and no major changes to coral cover have occurred since; 40% coral cover in 2000 and 43% in 2002. The monitoring program has demonstrated that the coral communities of Socotra have recovered strongly and consistently since 1998, particularly in the Nature Sanctuary protected zones of the MPA on Socotra Island. There is one exception, the shallow site near sea port in the General Use Zone. These coral communities near the port require particular management focus, and continued monitoring will be valuable to assess any future effects of climate change. From: Malek A. Abdulaziz, Yemen Environmental Protection Authority and Socotra Conservation and Development Program, malek\_asaad@yahoo.com, John Turner and Lyndon DeVantier.

the conservation and management of Yemen's vital coastal and marine resources, and the coral reefs in particular.

#### Eritrea

The biodiversity of Eritrea's coral reefs is of global significance. The prolonged disturbances ended in 1993 after 3 decades during which there were very low levels of human damage to the reefs. The coral reefs generally remain in very good condition, despite a moderate growth in tourism, some coastal development, and significant growth of commercial fisheries since independence. Coral cover ranges from 20-50% at most sites in the west of the Dahlak Archipelago, the islands near the port cities of Massawa in the north and Assab in the south. Cover occasionally approaches 100% at some sites. The coral eating mollusc *Drupella* usually occurs in high densities on many reefs, however COTS and coral diseases are comparatively rare. Development of commercial fisheries is now a high priority, including an aquarium fish trade that was discontinued in the late 1990s. Artisanal fisheries target pearl oysters, *Trochus*, *Strombus*, finfish, marine turtles and sea cucumbers.

The majority of the coastline is sparsely populated, with Massawa and Assab the two main population centres. Only 4 of the 350 offshore islands are inhabited, hence human stresses remain relatively low. Land reclamation, sedimentation, and resort developments in Massawa and on nearby islands may have damaged the adjacent coral reefs. There are signs of anchor and

diver damage on the few reefs visited by tourists, but curio collection is minimal. Eritrea has ratified several international conventions, including the Jakarta Mandate, the Convention on Biological Diversity, and CITES, but this has not translated into legal protection for the coral reefs. National environmental legislation has been drafted, but is unlikely to be implemented in the near future.

The Ministry of Fisheries is responsible for the conservation of marine biodiversity and for implementing a US\$5 million GEF funded biodiversity conservation project to conserve the coastal, marine and island ecosystems. The project includes a monitoring program for coral reefs and invasive species, and there are plans to establish 3 MPAs near Massawa and Assab, and a Coastal Zone Management framework. The Marine Biology Department of the University of Asmara in Eritrea will be responsible for rapid national marine biodiversity surveys and there are plans to develop a species conservation program for the turtle and dugong populations.

## CONCLUSIONS

**100 years ago:** The region was already receiving significant scientific attention, with many widespread Indo-Pacific reef species described. The Red Sea was already a major international shipping route, following the opening of the Suez Canal in 1869, with occasional shipwrecks and related oil spills. The Red Sea and Gulf of Aden have been trade routes for thousands of years and the reefs have supported artisanal fishers. There were no notable invasions of alien species through the Suez Canal, and damage from human activities was negligible.

**In 1994:** Most of the reefs were in good condition, with sustainable, although increasing, levels of fishing and other human pressures, except around the towns. Urban and tourism developments had caused major local damage to adjacent reefs. Some reefs in Egypt, Sudan and Yemen had been affected by COTS outbreaks, and minor bouts of coral bleaching in the early 1990s. Ship groundings in Egypt, Yemen and elsewhere had caused local damage. Reef and pelagic fisheries were expanding to supply increasing local, and export demands. There were few coral reef management activities in the region in 1994. The major national and regional environmental management initiatives started in the late 1990s, with PERSGA, in partnership with the Global Environment Facility (GEF), the United Nations Development Program (UNDP), the United Nations Environment Program (UNEP) and the World Bank.

**In 2004:** Urban growth, coastal land reclamation and fisheries are expanding, and COTS outbreaks are continuing. Tourism is expanding in some countries, but not in others. There has been strong recovery of some reefs badly damaged by the 1998 bleaching event, but others have shown no recovery. There have been notable successes in establishing MPAs, yet major challenges remain in developing an effective regional MPA network and managing some existing MPAs. Major gaps remain in survey and monitoring capacity, as well as most aspects of reef management.

**Predictions for 2014:** Increases in local and regional threats will degrade coral reef resources and reduce reef resilience. There will be increasing pressures from major coastal and port development, expanding fisheries, shipping and pollution, COTS outbreaks and climate change. These will cause reef deterioration, with reduced coral cover and lower fish stocks and biodiversity. As coastal development increases, there will be more damage to reefs around the larger ports and major tourist resorts. There is a serious and growing threat of major over-

exploitation of fisheries throughout the region, and both the regulations and enforcement mechanisms need to be urgently improved in most countries. Any repeat of the large-scale bleaching event of 1998 will prove catastrophic to reef communities in marginal conditions in the Gulf of Aden and southern Red Sea. It is highly likely that the combination of these impacts will lead to decreases in the health and extent of reefs, their renewable goods and services, and a loss in regional resilience. However, it is also expected that many healthy reefs will remain in the region, particularly those remote from development, and where local currents and upwellings moderate sea temperature fluctuations. These conditions will favour healthy reef growth, possibly the healthiest reefs in the world. Human populations in large parts of these desert areas will not expand therefore human pressure on coastal resources is expected to remain low.

## **RECOMMENDATIONS**

Most countries have laws for coral reef conservation, but the scope of the laws and the degree of implementation differs widely in the region. Stronger enforcement of national and international laws is needed in every country of the region, along with campaigns to raise public awareness of coral reef issues and the need to adopt sustainable management strategies. The priority actions needed to minimize the predicted damage to reefs have been identified in the Regional Action Plan coordinated by PERSGA in 2003. Steps have been taken to implement action, including the recent development of standard survey and monitoring methods, and improved management of some MPAs. However, there is insufficient capacity for effective reef management, or monitoring in most countries. The lack of capacity is an important regional issue, and major long-term programs of capacity building are urgently required.

## **REVIEWERS**

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## SUPPORTING DOCUMENTS

The key documents supporting this chapter have been prepared by PERSGA/GEF and PERSGA/ALECSO in 2003 and 2004. The following are on the PERSGA website: [www.persga.org](http://www.persga.org)

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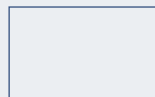
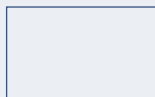
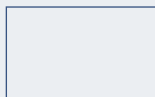
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### **SOCOTRA GROUP OF ISLANDS, REPUBLIC OF YEMEN - MAB SITE**

The Yemeni Socotra Islands, located at the entrance to the Gulf of Aden, were recognized as a UNESCO Man and Biosphere Reserve in 2003 and have been recommended for inclusion on the World Heritage Register, for which a nomination is currently being prepared. The islands, Socotra, The Brothers (Samha and Darsa) and Abd al Kuri and small islets, host outstanding levels of terrestrial endemism, and are important nesting sites for at least 10 species of seabird. The marine communities are also diverse, with some 250 species of reef-building corals, 730 species of coastal fishes and 120 species of algae, and are characterised by a unique “cocktail” mix of species representative of several marine biogeographic realms that merge here: the Red Sea and Arabian Sea, East Africa and the western Indian Ocean and the broader Indo-Pacific. For the time being at least, a small number of these species are known only from these islands, like many of their terrestrial counterparts.

These biological features, both terrestrial and marine, have sustained the islands’ human inhabitants for millennia, as the Socotrans have maintained a unique cultural identity, living sustainably off their land and seas. In 1997, the year that the Government of Yemen declared the islands a special natural area that required protection, the GEF invested five million dollars US in a United Nations Development Program (UNDP) implemented project titled ‘Conservation and Sustainable Use of the Biodiversity of the Socotra Archipelago’. With strong Government support, terrestrial and marine protected areas were established in September 2000, with a ‘Conservation Zoning Plan’ defining the various activities that are permitted and forbidden in different areas. The Yemen Environmental Protection Authority (EPA) has responsibility to implement the Plan. The local communities have actively participated in the process, with an increasing future focus on co-management. Yet significant challenges remain, with inappropriate development and harvest pressures continuing to build, and the Islands are therefore being carefully monitored and steered towards ecological and socio-economic sustainability.

**Ecological monitoring:** A long-term monitoring program has been in place since 2000 (Box p 148) established as part of the UNDP-GEF Socotra Biodiversity Project.

**Socio-economic monitoring:** A socio-economic monitoring program for fisheries was also established as part of the UNDP-GEF Socotra Biodiversity Project.

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**Coral reefs** are 5% of the natural resources.

**Ecological Monitoring** is effective.

**Socio-economic Monitoring** is effective.

Contributed by Lyndon DeVantier and Catherine Cheung

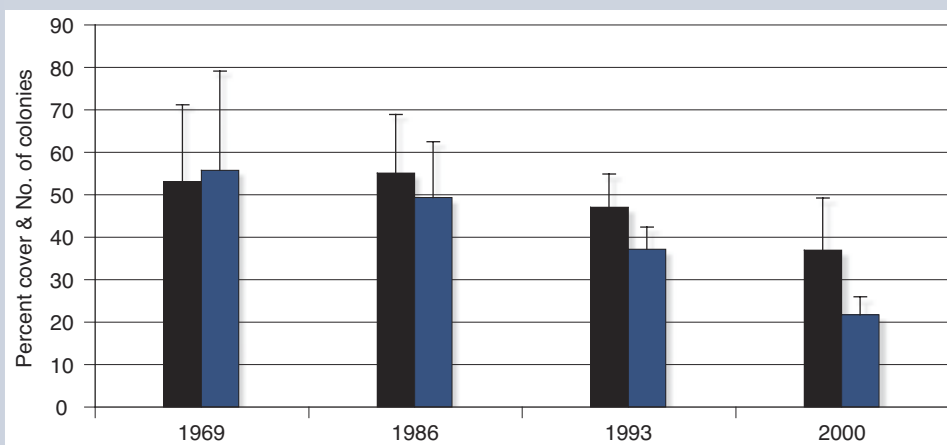
## THE CORAL REEFS OF EILAT, ISRAEL OR HOW TO KILL A CORAL REEF

The rapid growth of the city of Eilat, Israel, put increasing human pressures on the nearby reefs. There were 20,000 people in 1980, 40,000 in 1990, 54,000 in 1995, and 65,000 in 2000. The first signs of the damage to the reefs of Eilat (northern Gulf of Eilat/Aqaba, Red Sea) were in the 1980s and early 1990s, probably due to a combination of anthropogenic disturbances such as urban sewage, phosphate dust, groundwater inputs, sedimentation, tourist diving activities and port-ballast water. Many of these harmful activities were minimised by strict environmental enforcement, however the sewage from Eilat continued to flow into the sea until 1995, when a sewage treatment plant was built. The coral cover and colony abundance at the 'Japanese Gardens' in the Eilat Coral Nature Reserve (3-7 m depth) decreased by 33% and 56%, respectively between 1986 to 2000. These falls occurred when the levels of nutrients released from anthropogenic sources into the northern Gulf of Eilat/Aqaba showed a dramatic increase: in 1980 the total annual nitrogen release was  $5 \times 10^6$  mol Nitrogen; and phosphate release was  $0.24 \times 10^6$  mol Phosphorous. These quantities doubled in 1990, with the increase in population, but stopped in 1995 after the sewage was diverted away from the Gulf. The increased nutrients were considered to be the main cause for the decline in the corals. However, about this time, a new threat emerged; intensive net-pen fish farming started at the northern end of Gulf, and these have continued to grow exponentially. These fish farms use large fish cages, 12 m in diameter and 10 m deep, packed with gilthead sea bream *Sparus aurata*. The annual fish yield was 200 tons in 1991; it increased to 700 tons in 1995; and grew to a massive 2400 tons in 2000. All the waste food and fish faeces which falls through the cages either accumulates on the sea floor, or is carried by the currents through the northern Gulf.

These fish cages became the major anthropogenic source of nutrient enrichment releasing  $18 \times 10^6$  mol/year N and  $2 \times 10^6$  mol/year P. It is estimated that about 68% of the nitrogen and 27% of the phosphorus fed to the fish ends up back in the water as dissolved excreted products. In addition, 10% of N and 44% of P are dispersed as solids; hence, the annual amount of nutrients released into the surrounding water is 240 tons of N and 40 tons of P. It has been further shown that the particulate matter from the fish farms reaches the coral reefs 8 km further south. Indeed, much of the nutrient matter from the fish farms was carried further south and accumulated on the sea floor at 500 m.

These added nutrients set up a chain reaction: the nutrient enrichment stimulated phytoplankton blooms; the excess phytoplankton stimulated zooplankton production; and these are eaten by fish and the excess nutrients are passed up the food chain and distributed over the northern Gulf. The waste products of this stimulated chain reaction are deposited on the reefs and particularly into the deep waters of the Gulf. The surplus of nutrients have accumulated in these deep waters; but during winter, the cold surface waters sink and mixes with the deeper waters (i.e. vertical mixing) and effectively 'pumps' the nutrient-rich waters to the surface, resulting in 'macro-algal blooms' with the algae growing over and smothering the corals.

The deterioration of corals in Eilat occurred in two major phases. Between 1986-1994, all of Eilat's sewage flowed into the sea; and from 1995-present, the fish farms became the major anthropogenic source of nutrient enrichment in the northern Gulf. The sewage caused the major decreases of 14.7% in coral living cover and 24.6% in coral abundance. The fish farms grew exponentially from 1993 and contributed most of the additional nutrients, thereby causing a further decrease of 21.6% in coral cover and 41.9% in coral abundance. There has been further deterioration of corals of the northern Gulf in the last 4 years, since these measures were taken, due to diseases affecting the corals. Hence, the fish farms "replaced" Eilat's sewage as the major anthropogenic source polluting nutrients (equivalent to an urban sewage of a city counting 70,000 people) responsible for the continued deterioration of the reefs after 1995 to date. Today, the coral reefs of Eilat are severely damaged and exist in a critical state of health. From: Yossi Loya, Department of Zoology, Tel Aviv University, Israel [Yosiloya@post.tau.ac.il](mailto:Yosiloya@post.tau.ac.il). (Reference: Y. Loya (2004). The coral reefs of Eilat- past, present and future: Three decades of coral community structure studies. In: Coral Reef Health and Disease; Rosenberg and Loya (Eds). Springer-Verlag; Berlin, Heidelberg, New York. pp. 1-34).



Nutrient pollution from urban sewage and fish farm wastes have resulted in a steady loss of coral cover and coral colonies in the 'Echinopora zone', (3-7 m depth) at the Eilat Coral Nature Reserve. The bars on the left are average live coral cover (%) and the bars on the right are average number of coral colonies along permanent 10 m line transects ( $\pm$  SD = standard deviations; n = number of transects).

## 5. CORAL REEF STATUS IN THE ROPME SEA AREA: ARABIAN/PERSIAN GULF, GULF OF OMAN AND ARABIAN SEA

HAMID REZAI, SIMON WILSON, MICHEL CLAEREBOUDT  
AND BERNARD RIEGL

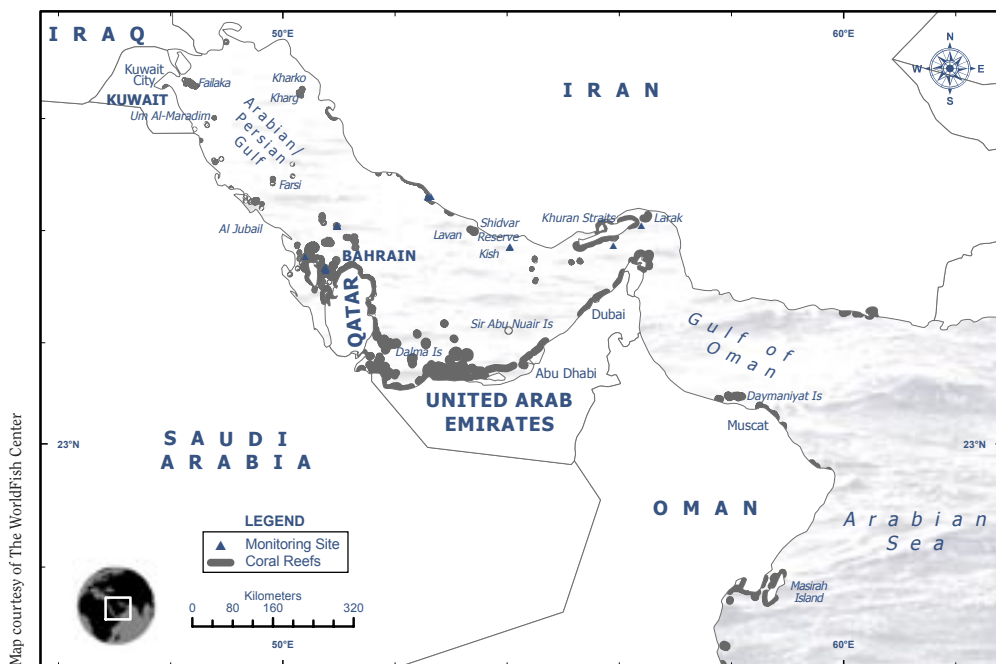
### ABSTRACT

This report summarises the status of coral reefs in the ROPME Sea Area which includes Bahrain, Iran, Kuwait, Oman, Qatar, Saudi Arabia and United Arab Emirates (UAE); there are no coral reefs in Iraq. The region can be split into three parts according to the local marine climate, which strongly influences the nature of the coral communities: the Persian/Arabian Gulf (hereafter called 'the Gulf'); the Gulf of Oman; and the Arabian Sea.

The Gulf region was amongst the worst affected by coral bleaching events in 1996, 1998 and 2002, which reduced live coral cover in many shallow areas to less than 1%. There has been very little recovery, except in a few areas close to deeper water and away from additional human impacts. Coastal engineering, land reclamation and dredging are causing significant environmental damage along the mainland coast, particularly in UAE and Bahrain, while offshore islands are protected either actively (as MPAs) or passively (as military or industrial zones). Any future coral reef conservation effort must be concentrated on these islands in order to be effective.

Coral communities in the Gulf of Oman and Arabian Sea remain in good condition, due in part to the mitigating effects of the summer monsoon upwelling that cools summer seawater temperatures. Coral cover in the Gulf of Oman is typically 30-40% at depths of 4-12 m, but live cover decreases very rapidly in deeper water. This range is consistent with earlier results and suggests that the condition of corals in the Gulf of Oman has not changed significantly in the past 10 years, although there is considerable temporal variability of live cover at some sites due to crown-of-thorns starfish (COTS) outbreaks and periodic recruitment episodes. Unlike the Gulf, coastal industrial development in coral rich areas in Oman does not generally involve large-scale land reclamation or dredging, although the discharge of cooling water is a concern in one area. Fishing remains the major human threat to coral communities in this area.

**100 Years ago:** Reefs were almost certainly healthy. They were simple reefs, dominated by *Acropora* (staghorn) corals to about 4-5 m depth, then by massive corals (*Porites*, faviids) from



5 m to about 10 m. Their diversity was lower than in the Indian Ocean due to natural causes including limited recruitment since the last ice age (Holocene), severe annual variation of temperature, and extreme salinity.

**In 1994:** Corals remained in similar condition in most areas. However, nearshore substantial construction, landfill, and oil and civil development removed much coastal habitat. This applied to seagrass areas as much as to reefs, though the sedimentation particularly affected the nearshore reefs. There were few activities to conserve and manage coral reef resources. The Jubail Wildlife Sanctuary was the first MPA and it was established after the 1992 Gulf War.

**In 2004:** Coral bleaching events in 1996 and 1998 had a profound effect on these reefs. The entire shallow water staghorn zones were killed in many areas. In 2004, many of these areas have been reduced to rubble, with no sign of recovery, and the mobile rubble may be impeding new recruitment. Some sites do show some recovery, especially in deeper water where there is significant recruitment of faviid species that were previously relatively minor components of the reefs. Consequently there appears to be a shift in the species that are dominating the Gulf reefs. Levels of estimated reef destruction range widely within the region, from a low of 1% in Oman to a high of 97% in Bahrain. There is rising awareness of coral reef conservation issues, but the region lags well behind much of the rest of the world.

**Predictions for 2014:** The shallow *Acropora* reefs are unlikely to recover because forecasts for sea surface temperatures (SST) indicate that future temperatures will be unfavourable for coral growth. Deeper reefs will increase their coral cover, probably with a shift in the dominant species. As has happened in the past, continuing landfill arising from development will add stresses to nearshore reefs, causing further degradation.

## INTRODUCTION

This chapter summarises the status of coral reefs in countries bordering the Regional Organisation for the Protection of the Marine Environment (ROPME) Sea Area (Bahrain, Iran, Iraq, Kuwait, Oman, Qatar, Saudi Arabia and United Arab Emirates). There are no corals in Iraq. This is an update of the corresponding chapter in Status of Coral Reefs of the World: 2002 report.

Three basic marine climates occur in the ROPME Sea area. Extremes of temperature and salinity characterise the Gulf and constrain the development of coral reefs. Seawater temperatures can exceed 34°C in summer and be less than 15°C in winter; this is the world's greatest annual temperature range for corals. Salinity in the Gulf is also very high, generally greater than 45 ppt, while in the shallow waters between Bahrain and Qatar, salinity often exceeds 50 ppt. In terms of temperature and salinity, the few corals in the gulf of Salwah and the reefs of the western coast of the UAE probably face more 'extreme' conditions of higher and lower temperatures than those of other areas (e.g. Kuwait). Conversely, the reefs of Kuwait are exposed to a very heavy load of particles due to the shallow water environment and input from the Shatt Al-Arab. These conditions do not affect the reefs of Saudi Arabia or the Western UAE.

Temperatures in the Gulf of Oman are moderate in comparison to the Gulf. Typical winter temperatures fall to 22-23°C, while summer temperature is characterised by a highly fluctuating regime caused by the rise and fall of a shallow, but strong thermocline. Summer temperatures range between 23-31°C, and often cover this range within a day. Salinity is a constant 36.5 ppt. The southern seaboard of the Arabian Peninsula experiences a strong and persistent upwelling during the summer monsoon season. Water temperatures can drop to 16°C but are more typically around 18-20°C, and reach their annual maximum of about 30°C just before the monsoon starts. The northern Arabian Sea is eutrophic for 5-6 months of the year, due to the nutrients carried in by the upwelling, resulting in the development of seaweed beds and algal blooms. Salinity is typically 34 – 35 ppt.

The pattern of coral diversity and reef building reflect these different marine climates. Coral diversity and reef building potential in the Gulf is low (less than 40 species) as a result of the extremes in water temperature and salinity that are close to the physiological tolerance limits of many species. Recent work has identified 107 reef-building coral species in the Gulf of Oman, while the species count for the Arabian Sea sector of ROPME is likely to be slightly higher as the influence of the wider Indian Ocean becomes increasingly important along the gradient towards East Africa. In both the Gulf of Oman and the Arabian Sea, reef building potential remains low due to high rates of bioerosion fuelled by primary production from the Arabian upwelling system. The ROPME coral fauna is a sub-set of the Indo-Pacific fauna, mixed with regional endemics, with faviids particularly well represented and acroporiids and fungiids significantly under-represented. At least 10 Southern Arabian endemic species are now known, including two endemic genera *Parasimplastrea* and *Calathiscus* and the taxonomic position of several other species has yet to be confirmed.

## STATUS OF CORAL REEFS

### Kingdom of Bahrain

Coral reefs in Bahrain are mainly distributed around the northern and eastern coastlines. Reefs are of special environmental and economic importance, but their growth, structure and distribution are limited to a few areas by extreme temperatures, salinity and high sediment loads. The reefs include: Fasht Al Adhom; west Fasht Al Dibal; Khwar Fasht; north Jabari; Fasht Al Jarim; Samahij; and Abul Thama. Live coral cover at all sites around Bahrain is very low following widespread mortality in 1996 and 1998. Recovery over the past 6-8 years has been very slow, hindered by an accumulation of silt resulting from extensive landfill. The only significant population of living coral in Bahrain surrounds Abul Thama, a small raised area surrounded by 40 m deep water, about 72 km north of the main island.

### Islamic Republic of Iran

The coastline of Iran is approximately 2000 km along The Gulf and the Gulf of Oman. Corals are mostly restricted to the offshore islands on the Gulf coast of Iran that are often protected passively by military bases. This also restricts access to these islands for scientific work, such that many of the important coral areas in Iran remain un-surveyed. Much of the Iranian coast in the Gulf of Oman is sedimentary and exposed, therefore unsuitable for coral growth, although important areas of corals probably exist in the more sheltered bays such as Chah Bahar. There is a need for surveys on this coast to describe coral distribution and composition.

Of the known coral rich areas, Farur (19 ha), Farurgan (2.5 ha), Sirri (16 ha), Lavan (18 ha), Hendourabi (20 ha), Kish (62 ha) and Larak (16 ha) islands have been surveyed in the past 10 years, and Kish Island is now a Reef Check site. *Tubastraea* spp., *Heteropsammia* sp., *Dendronephthya*, *Sarcophyton*, *Antipathes* sp. and the gorgonian *Subergorgia suberosa* have been reported from these islands for the first time. It is likely that more detailed work will reveal some better-developed reefs in the Gulf because of the deeper water, slightly lower temperatures and more stable salinities found nearer the Straits of Hormuz.

Other reef sites are known, but have not been surveyed, e.g. the islands of Khark (181 ha), Kharko (266 ha), Nay Band (181 ha), Shidvar (13 ha), Hormuz (59 ha), Hengam (36 ha), Tonb-e-Bozorg and Tonb-e-Koochak (21 ha), Queshm Island and Aboomusa (11 ha). The best-developed reefs are in Kharg, Farur, Farurgan and Larak Islands. Surveys in the 1970s and 1980s indicated live coral cover ranges from 9% on Kish Island, to 30% on Nay Band Bay, with hard coral extending from 3 m to 15 m depths.

### State of Kuwait

The most northerly reefs in the Gulf lie around the southern islands, particularly the islands of Kubbar, Qaru and Um Al-Maradim, where they occur in extreme oceanographic conditions with relatively high sediment loading. In this extreme environment, species diversity is relatively low (35 species). Overall the zooxanthellate coral fauna includes 29 species, and the others are not usually considered as 'reef builders'. Coral communities occur as platforms, patches or fringing coral assemblages and the most important and dominant reef builders are *Porites harrisoni*, *Acropora arabensis* and *A. downingi*. Considerable new research has taken place in Kuwait recently, resulting from surveys connected with the claims for compensation following the Gulf War. The distribution and composition of the coral communities and the fish life they support were reviewed recently.



### Sultanate of Oman

Major coral growth occurs in four regions along the varied shores of the 1700 km coastline: the Musandam Peninsula; the Capital Area coast, including the Daymaniyat Islands; the Gulf of Masirah; and the Dhofar coast from the Al Hallaniyat Islands to Mirbat. Although the coral communities are relatively diverse, Oman's reefs are only marginally developed, especially along the Arabian Sea coast. The exception is the country's only true reef which is south of the Barr al Hickman peninsula in the Gulf of Masirah with large areas of monospecific stands of foliose *Montipora* sp. Elsewhere *Porites* is the most important reef builder, and extensive monospecific carpets of *Pocillopora* and *Acropora* are common features. Reef development appears to be limited by high rates of bioerosion, which are facilitated by the productive waters, and frequent lesions made by grazing predators (e.g. COTS and parrotfish).

Recently, 107 species of reef building corals were recorded in the Gulf of Oman, and an additional 20 species probably occur on Oman's Arabian Sea coast. About 15% of these corals are regionally endemic and about 10% are new species, which are being described. These results confirm earlier reports that Oman's coral fauna is unusual because some families are strongly under-represented (Acroporidae and Fungidae) while other families are over represented (e.g. Favidae, Poritidae).

Coral cover in the Gulf of Oman is typically 30-40% at depths of 4-12 m, but live cover decreases very rapidly in deeper waters. This range is consistent with earlier results and suggests that the condition of corals in the Gulf of Oman has not changed significantly in the past 10 years, although there is considerable temporal variability of live cover at some sites due to COTS outbreaks and periodic recruitment episodes. During the summer, upwelling of cool water is at its greatest in central and southern parts of Oman, apparently limiting the incidence of warm water bleaching.

There are often rapid changes in these dynamic communities. Cover at Qibliyah Island in 2002 was moderate in shallow areas (10 m depth), with about 25-30% live cover of the *Acropora* and *Porites* community, and 30-40% cover of dead, intact *Acropora* tables, suggesting significant mortality had occurred within 12-18 months, probably due to a COTS outbreak. A repeat of the 1998 survey in 2003 near Sur showed an average increase in coral cover of about 5% (from 10% to 15%) caused largely by widespread recruitment of *Acropora* species. Frequent disturbances and pulsed recruitment characterise the coral community dynamics throughout the region. Recruitment rates in the Gulf of Oman and the Arabian Sea are about a third of those in the Central Indian Ocean, with the most abundant juvenile corals in Oman being faviids, while the success of recruitment of *Acropora* appears to pulse strongly every few years.

Damage from the 1998 bleaching event in Oman was slight, with some mortality affecting shallow communities in Dhofar. Since then a number of minor and localised bleaching events were reported in 2000, 2002 and 2004 (Muscat Area), but none resulted in significant mortality. However, the frequency of bleaching indicates that corals are living close to their lethal limits during summer, particularly in Musandam where average summer temperatures frequently reach 32°C.

### State of Qatar

Conditions for coral growth are best on the northern and eastern coasts of Qatar, while the western coast is subject to extremes of temperature and salinity. The coral fauna found in Qatar

is similar to that in UAE, with 18 species recorded, although this figure would probably rise with further study. The best coral growth in Qatari territorial waters is on the offshore islands, including Halul Island where strong *Acropora* regeneration has occurred recently. This island, however, contains the main oil and gas marine terminal of Qatar Petroleum and is subject to significant human impacts including dredging for harbour construction and marine outfalls. There has been very high coral mortality in the past 10 years from bleaching and human impacts, particularly affecting the shallow coral communities on the mainland coast, from Fasht al Dibal to Khor Al Oudeid. For example, several hectares of shallow (1-4 m) *Acropora* beds, with *Porites* mounds east of Doha suffered nearly 100% mortality in 1998. Prior to 1998, heavy siltation from construction of a breakwater and land reclamation for the new Doha International Airport severely stressed these communities. At other sites near the mainland, there is about 10% live cover of *Porites* or *Cyphastrea* remaining.

Despite the severe degradation of shallow communities, coral reefs in deeper water have some live coral cover, presumably because of reduced mortality from thermal stress. The new data from Qatar are from seabed surveys for environmental impact assessments or engineering works. Much of the seabed surrounding the oil and gas rigs in the eastern sector of the Qatari exclusive economic zone (EEZ) is a flat limestone cap rock with an occasional veneer of sediment. Coral communities can grow where this platform rises slightly, and are usually dominated by faviids and siderastreids. Although the live cover of these communities is low (5% or less) they may provide brood stock for future recovery of shallow communities.

### **Kingdom of Saudi Arabia**

Corals on The Gulf mainland are mostly limited to small pinnacles or outcrops, and patch reefs between Ras Al-Mishab Saffaniyah and Abu Ali, and between Abu Ali and Ras Tanura. The most developed and most diverse reefs are around 6 offshore islands, particularly Jana and Karan. However, like most Gulf sites, bleaching devastated the corals. For example, around Karan Island, live cover on the reef slope was 33% in 1992, but dropped to 23% in 1994 and to 1% in 1999 after mass coral mortality in 1996 and 1998 when temperatures exceeded 34°C. Coral communities in the lagoons did not decline in cover, presumably because they are acclimatised to more extreme temperatures. Corals at Abu Ali suffered a similar fate with mortality of about 99%, and only small patches of coral tissue on the regionally endemic *Porites harrisoni* survive. No colonies of the extensive *Acropora* communities recorded in 1994 on the eastern tip of the peninsula were found alive in 1999.

### **United Arab Emirates**

The coastline of the UAE extends 650 km along the southern shore of the Gulf and for 90 km along the Gulf of Oman to the east. However, the total coral reef area, which occurs as shoals and around the numerous offshore islands, is about 1,190 km<sup>2</sup> because the entire EEZ is less than 20 m deep. Many similarities exist between Dubai's coral communities and those of other parts of the Gulf particularly Qatar, Bahrain, Saudi Arabia and Iran. Notable absences from the UAE fauna include *Montipora*, *Pocillopora*, *Goniopora*, all fungiids, agariciids, and oculinids, alcyonaceans, as well as hydrozoans, although many of these taxa are found elsewhere in the Gulf and on other high-latitude reefs in the Arabian region. In general, coral cover, and recovery, was better towards the east than in the west.

Excellent coral growth occurs around Sir Abu Nuair Island (Sharjah Emirate) with probably the best *Acropora* stand in the southeastern Gulf. These corals were severely bleached in 2002

but recovered, probably because they have a degree of acclimation. The *Acropora* bleached much less than the faviids and poritids; a complete reversal from the situation in 1996.

A large MPA, which includes the islands of Bazm al Gharbi and Murawwa, has been declared and managed by the Environmental Resource and Wildlife Development Administration, with the support of private landowners. This area contained some of the densest coral growth in the Gulf before the bleaching in 1996 and in 1998. The area is well managed and has high potential to recover at least partially. Dalma Island off western Abu Dhabi had rocky outcrops and platforms covered with a veneer of corals in 1996, with large areas of *Acropora* and an under-storey of *Porites*, *Platygyra* and *Favia* spp at depths of 1-4 m. Greater depths were often dominated by large *Porites* colonies and an under-storey of *Acropora*. *Porites*-dominated reefs are also particularly well developed at Bu Tini shoals in Abu Dhabi, where *Acropora* has survived recent bleaching events in pockets protected by *Porites* bommies.

The highest cover and diversity of corals along the mainland coast of Dubai is in the Jebel Ali Wildlife Sanctuary. The Sanctuary has a wide diversity of habitats (lagoons, seagrass beds and coral communities) that are all close together and have strong ecological links. The area was hit hard by bleaching in 1996 and 1998 but recovery is strong, probably due to the availability of new recruits from deeper water. Until recently, this was the only stretch of the Dubai coastline free of industrial development, dredging and land reclamation, however, management of the sanctuary has now been provided to the Palm Island Development Corporation. They are reclaiming huge shallow areas for real estate development as part of the damaging Palm Island and Palm II developments. These mega-projects involve massive scale dredging and reclamation, and are expected to have very negative impacts on the entire coastal ecology of Dubai.

## THREATS TO REEFS

### Temperature, Bleaching and Upwelling

Bleaching during 1996 and 1998 devastated coral areas throughout the Gulf, reduced live coral cover to less than 1% in some areas, and may have resulted in local extinctions of certain species. Recovery has been patchy, with rapid recovery and apparent acclimation of more susceptible species in places, while in other areas there is little or no recovery. These latter sites frequently experience other stresses, which in the Gulf are most likely to be sedimentation from dredging and land reclamation, or industrial pollution from cooling water discharges.

The current recovery is limited and involves different species to those, which dominated previously. Recovery in some locations indicates the capacity of the system to gain new recruits from unidentified sources, presumably corals growing in waters deeper than about 10m. However, faviid corals rather than *Acropora* and *Porites* now dominate many of the affected coral areas. This may represent a stage in the ecological succession or a permanent phase shift towards species capable of withstanding higher temperatures. It is predicted that higher temperatures will occur in the Gulf in future. A minor bleaching event occurred in Musandam in August 2003 while seawater temperatures were being monitored. This showed that the critical threshold for bleaching in the Straits of Hormuz is close to 32.5°C, as a nearby site did not bleach at lower temperatures. In the northern Persian Gulf islands of Iran, bleaching has occurred annually, although with varying intensity.

The contrast in the patterns of bleaching between the Gulf and the Gulf of Oman and Arabian Sea is very striking. There is a strong thermocline in summer in the Gulf of Oman that separates

heated upper water from cooler water arriving with the monsoon upwelling. Thus there is a rapidly fluctuating thermal environment, which protects corals from bleaching. Should the monsoon that induces the formation and movement of this protective thermocline fail or weaken, bleaching can result. This was the case in early 1989 and in 2000, 2002 and 2004. In each case, there was localised bleaching that was not severe enough to cause mortality. Upwelling in the Arabian Sea during the summer months also provides a more secure thermal refuge for corals.

### **Crown-of-thorns Starfish (COTS)**

The persistent presence of COTS, coupled with the occasional population outbreak, are key factors influencing the dynamics and community structure of coral communities in much of the region, particularly in the Gulf of Oman and Arabian Sea. COTS numbers are probably influenced by the timing and strength of upwellings that control larval and juvenile survival rates, as well as prey availability (which appears to be limiting in Dhofar). Low-level COTS infestations in the Muscat area resulted in localised changes to community structure from 2003 – 2004. For example, the coral community at Kalbuh near Muscat was dominated by *Acropora* in 1996, but has not returned to its original structure by 2004 following a COTS infestation in 1997. COTS have also been reported in the Gulf where they appear to have a far smaller influence on reef formation and community structure than in the Gulf of Oman.

### **Disease**

Little is known about the incidence of coral disease, and the effect it may have on coral community structure in the region. An apparently new disease to the region, Yellow Band Disease, has recently been reported from the Gulf, and at two sites in the Gulf of Oman; the Daymaniyat Islands and at Qalhat. Instead of exposing white skeleton, corals attacked by the disease retain a characteristic yellow colouration in the skeleton. Black Band and White Band Diseases have also been reported in UAE, and observed in the Gulf of Oman. Cancerous growths and hyperplasms are common in Omani waters and have been reported from the Straits of Hormuz, Gulf of Oman and Arabian Sea areas.

### **Bioerosion**

Erosion of live corals and dead coral skeletons severely limits the accumulation of a limestone framework and therefore the formation of true reefs within the region, although it does not seem to have a significant effect on the diversity or distribution of corals. In Musandam, cliff erosion by the date mussel *Lithophaga* destabilises substrates and induces rock falls, which may limit reef development in some places.

The principal agents of bioerosion include boring algae and sponges, *Lithophaga*, and the echinoids *Diadema* sp. and *Echinometra mathaei*. *Diadema* forms the densest accumulations, massing on talus areas around the bases of live coral colonies, while in Kuwait high densities of *E. mathaei* are a feature of reef flats. In the Gulf of Oman and the Arabian Sea, the standing stock of urchins is probably higher than in other reef areas because of the high primary production rates of algal turf. Furthermore greater densities of filter feeding internal borers are supported by the greater abundance of phytoplankton and bacteria found in upwelled water. Indeed, in Oman it is common to find healthy colonies of *Platygyra* that are completely hollow because their skeletons have been completely eroded, leaving a thin shell of carbonate and living tissue.

The high incidence of bioerosion weakens corals and makes them more susceptible to physical damage from storms or anchor strikes. In Oman, 35-40% of *Acropora* colonies at Qalhat in the Gulf of Oman were either not attached firmly to the seabed or upside-down.

## CORAL BLEACHING AND DISEASE IN THE NORTHERN PERSIAN GULF

Coral bleaching has been studied on the Iranian side of the Persian Gulf at Kish, Farur and Hendourabi islands on permanent transects at shallow (3 - 6 m) and intermediate (6 - 12 m) depths. In 1999, 30% of shallow corals were bleached around Kish Island, especially massive *Favia spp.* and sub-massive *Porites* species with typically 70% of each colony showing surface bleaching. In 2000, there was bleaching of 10% of shallow and 5% intermediate depth corals of Farur Island with about 50% of each colony affected. There was simultaneous, but less serious, bleaching in Nay Band Bay (5% shallow and 1% intermediate corals), with 70% and 50-70% of each colony was affected, respectively. No bleaching was observed on Kish Island in 2001, but in 2002, there was minor bleaching of 1% of shallow corals around Kish and Larak islands with 40% and 30% of each colony affected, respectively. In 2003, 1% of the corals in Nay Band Bay at both depths were bleached (10% of shallow and 70% of deeper coral colony area affected). Therefore it appears that the incidence of coral bleaching declined between 1999 and 2003 in the northern Persian Gulf. Most of the bleached corals were in shallow water (1 - 30%), with 10-70% bleaching on each colony. Corals in deeper water were less affected (1-5%)..

*The incidence of coral bleaching and disease on corals reefs in the northern Persian Gulf, Iran appears to be decreasing in recent years. Bleaching is more likely to affect shallow (3-6 m) water corals whereas the Yellow-Band Disease affects corals more in intermediate (6-12 m) depths.*

Study area	Year of survey	% of coral bleached		% of colony bleached		Disease (type/%)	
		3-6 m	6-12 m	3-6 m	6-12 m	3-6 m	6-12 m
Kish Island	1999	30	0	70	0	0	0
	2001	0	0	0	0	0	YBD<1
	2002	1	0	40	0	0	YBD<1
Nay Band Bay	2000	5	1	70	50-70	0	0
	2003	1	1	10	70	0	0
Larak Island	2002	1	0	30	0	0	0
Farur Island	2000	10	5	50	50	0	YBD<5

The first incidence of Yellow-Band Disease (YBD) on corals in the northern Persian Gulf was around Farur Island in 2000. Less than 5% of corals were diseased at 6-12 m. There was a low incidence (less than 1%) at intermediate depths (6-12 m) around Kish Island in 2001 and 2002. The affected species were *Porites sp.*, *Favia pallida*, and *Platygyra daedalea*. This disease was previously reported from the Southern Persian Gulf and Gulf of Oman. Thus it appears that intermediate depth corals (6-12 m) are the most susceptible to YBD in the northern Persian Gulf. From: Mohammad Reza Shokri, University of Newcastle, Australia, Mohammad.Shokri@studentmail.newcastle.edu.au

## HUMAN IMPACTS

### Dredging and Landfill

Land reclamation and dredging in the Gulf have altered the coastal ecology in such widespread and fundamental ways that little of the original coastline remains around the major cities and industrial areas. The impact extends beyond the shoreline because turbidity and suspended sediments are dispersed from the dredge or reclamation sites. In addition, coastal currents are diverted by coastal engineering, altering the movement of sediment which accumulates. Landfill around Bahrain, Saudi Arabia and UAE have been particularly damaging to the coastal ecology, while alterations to the coast of Kuwait, Iran and Oman have been more localised. In Kuwait, major disturbance to the reef at Umm Al-Maradem has been caused by the Coast Guard base and harbour construction.

Three very large land reclamation projects have started in UAE in the past 2 years: Palm Island; Palm II; and the World Island. These real estate developments are fundamentally changing the ecology of Dubai's coastline. Large areas (several km<sup>2</sup>) of seabed are filled, there are impacts from dredging sites, and there are changes to current patterns along the coastline. Palm II is being built over the Jebal Ali Marine Sanctuary where corals occur in one of the few MPAs in UAE. These projects are particularly destructive and there has been minimal environmental management attempted to mitigate the negative impacts. Maintenance dredging and expansion of Jebal Ali Port also releases large volumes of suspended sediments into the coastal environment, further damaging the rich coral areas to the east and west.

In Bahrain, land reclamation on the northern and eastern coasts have increased the urban area by 11 km<sup>2</sup> in less than 10 years, while also damaging valuable shallow coastal resources, including coral reefs. Large amounts of sediment were dispersed directly towards coral areas around the Muharraq dredging area, with about 182,000 m<sup>2</sup> of reef area lost between 1985 and 1992. There are now proposals to reclaim part of major coral reef areas at Fasht Al Adhom, and construct a causeway linking Bahrain with Qatar, further damaging reefs and disrupting currents in the Gulf of Salwah. Despite government regulations controlling impacts from land reclamation, there is little enforcement and many projects are completed without formal government approval. About 10 suction dredgers routinely operate in Bahrain's waters, including specialised cutter dredges capable of working in areas of weak rock, such as coral reefs. Extensive new housing developments are planned for areas currently offshore.

Elsewhere in the region, dredging for navigation, port and harbour construction, road-building and reclamation also occur but on smaller scales. For example, the reclamation of Khasab mud flats in Musandam was completed during construction of a large port complex which was intended to encourage tourism, but these have disturbed nearby coral communities and destroyed a significant seagrass bed.

### Fishing

Damage to coral communities from nearshore gillnet fishing goes largely unreported in the region but is noted as a concern in Oman's Coral Reef Management Plan (1996) and National Biodiversity Strategy and Action Plan (2000). The main issue near reefs in Oman is the loss or abandonment of gillnets which entangle and damage the corals, and reduce tourism potential. Periodically the Ministry of Environment combine with dive clubs to remove fishing nets,



traps, and anchors from popular dive sites. Fishing debris is the most common category of waste on beaches of the Gulf of Oman, indicating that there is a larger impact underwater. In the UAE, abandoned fish traps continue ‘ghost fishing’ for weeks before the trap corrodes and becomes ineffective.

### **Recreational Activities**

Some areas attract significant numbers of recreational divers, bringing with them the risk of anchor damage, especially in heavily used sites. Many of the most popular areas now have permanent mooring buoys e.g. areas in Kuwait, Daymaniyat Islands, Fahal Island, Bandar Jissah and Bandar Khayran in Oman. However, there are still reports of divers damaging corals in isolated areas e.g. Kish Island, Iran. Currently, diver pressure is within the carrying capacity at most sites, although tourism is being promoted throughout the region. Therefore, it is important to ensure that protective measures match rising tourist numbers.

### **Oil and Industrial Pollution**

More than half of the world’s ocean-transported crude oil passes through the Strait of Hormuz, and a major new pipeline is being planned for transporting gas from Qatar via UAE to Oman for export. The major sources of marine oil pollution are: tank washings; discharge of oily bilge water; operational spills during loading and unloading; leaks associated with offshore drilling and oil production; major oil spills; and war. Oil pollution can affect the long-term vitality of corals and other reef organisms by affecting their reproductive cycle and early life stages. Coral larvae float to where they are susceptible to the effects of floating oil. The abundant supply of gas from Qatar, UAE and Oman is driving rapid industrial development, often near coral rich areas, e.g. at Qalhat in Oman where gas and fertilizer industries are developing and expanding. New waste oil reception in Fujairah in UAE has reduced the volume of tanker washings at sea, which may have reduced the volume of tarballs found on Gulf of Oman beaches. Offshore oil and gas exploration and production is continuing in Qatar, UAE and Oman, thereby providing additional risk of damage to coral areas. Exploratory drilling in the Straits of Hormuz failed to find significant gas reserves, but further exploration is currently underway in and around the Gulf of Masirah in Oman.

Cooling water discharges from desalination and power plants are generally 10°C or more above the ambient temperatures and contain anti-fouling (chlorate) and anti-scaling chemicals. These thermal discharges near coral reefs add to the risk of bleaching, while chlorinated compounds contaminate the food chain and affect growth and reproductive output. The boom in industrial development, power production and desalination in the region, will increase the volume of heated water discharged into an already overheated system. Coral rich areas at risk from thermal discharges include Bahrain, Jebal Ali Marine Sanctuary (UAE), Bushehr (Iran), Ruwais (UAE) and Qalhat (Oman).

## **CONSERVATION AND MANAGEMENT ISSUES**

### **Law, Enforcement and Institutional Capacity**

There are sufficient legal instruments to protect the marine environment in most countries, including the principles and guidelines laid down by ROPME. For example, UAE Federal Law no. 23, 1999 on the Exploitation, Protection and Development of Marine Biological Resources specifically protects coral areas. However, this essential legislation is insufficient to reduce damage to reefs without sufficient enforcement capacity within governments; and many countries have no capacity. There are few effective NGOs in the region and the universities



are largely silent on environmental concerns. Notable exceptions are a small WWF presence in UAE and the newly formed Environmental Society of Oman (ESO). Many universities are funded by the oil industry and heavily occupied in teaching.

### **Strategic Planning**

Saudi Arabia has developed a National Action Plan for Coral Reef Conservation, which focuses on improving the knowledge base about coral reef ecosystems in its territorial waters and reducing human induced pressure. Oman has a National Coral Reef Management Plan (1996), and National Biodiversity Strategy and Action Plan (2000); these plans were developed to manage natural resources, but little has been done to convert plans into action in the region. Regional cooperation in coral reef management has recently improved with a regional conference in Riyadh on coral bleaching (2000), a workshop in Kish Island (2003) and a meeting in Tehran (2004).

### **Marine Protected Areas**

These are a key tool for protecting coral reef areas, but existing MPAs throughout the region require significant improvements in their management to become truly effective. For much of The Gulf, MPAs need to be established on offshore islands away from the rapid coastal developments that have already damaged some areas of high conservation value e.g. Murawwa Island (UAE). Similarly in Oman, management of the Daymaniyat Islands National Nature Reserve needs to be strengthened to meet the conservation objectives.

### **Public Awareness, Research and Monitoring**

The long-term success of conservation efforts requires public acceptance and support, and a sustained education and public awareness campaign is required for issues as complicated and remote as out-of-sight coral reefs. An interactive CD has been developed in Oman for all schools in Oman describing the marine environment (including coral reefs, seagrasses, mangroves, beaches). The authors could find little information on the reefs of this region; a clear indication that more applied research is required. It is widely accepted that research and monitoring are important to support reef management, especially in MPAs, but there are no consistent research or monitoring programs in place. The reason is often a lack of trained personnel, equipment and financial resources, but more importantly a lack of awareness and political will in governments.

## **RECOMMENDATIONS**

To improve research and coral monitoring, the following recommendations are advanced:

- Develop national coral reef policies followed by establishing focal points within the existing institutions to coordinate research and monitoring among national and foreign scientists;
- Implement the policies, both those that exist and new ones recommended above. In this region above all else, there is scant regard for much of the existing regulation.
- Calibrate or standardise monitoring survey procedures, data storage, analysis and reporting, using regional (PERSGA - ROPME) and international protocols (e.g. Reef Check, GCRMN); and
- Provide financial support through ROPME, ICRI, ICRAN, ICLARM, IOC-UNESCO for training of coral reef monitors and scientists, and initiate coral reef monitoring, analysis and reporting projects.

To improve the conservation, management and sustainable use of coral reefs, the following recommendations are suggested:

- Implement national coral reef policies and where necessary develop or refine legislation regulating use of reef resources, including MPAs;
- Enforce the regulations relating to MPAs, fisheries and resource use, both those that exist and new ones recommended above;
- Provide financial support through ROPME, ICRI, ICRAN, ICLARM, IOC-UNESCO for capacity-building and training of coral reef MPA managers; and
- Develop and expand education and awareness programs.

## CONCLUSIONS

The Gulf area has been very badly affected by global warming, with greater coral mortality than most areas. The prognosis for some groups of corals and reefs, notably the shallow *Acropora* dominated reefs, is not good. Recruitment is occurring in many other areas, particularly of faviids, although this appears to be changing the coral reef community in many locations, with unknown consequences. In many states, there are apparently strong portfolios of environmental regulation. The problem lies not in the need for more legislation, but in the need to adhere to and enforce the existing provisions. There have been more management plans, protocols, surveys and protected area declarations and proposals than in most other areas of similar size in the world. However, the environmental bodies have clearly much less influence than the development bodies, which prefer to build over the sea rather than on the vast empty interiors. This creates problems which are beyond the capacity of nearshore reefs to sustain.

“I have already had occasion to speak, in the course of my travels, of the astonishing mats of works formed by marine insects; namely the immense banks of coral bordering, and almost filling up, the Arabic Gulf... The reader may therefore conceive with himself what a variety of madrepores and millepores are to be met with in these seas” (Niebuhr 1792).

**100 Years ago:** The vast oil reserves of the region had not been developed, and human uses of the marine area were mostly small-scale traditional fishing and pearling. Reefs were almost certainly vibrant, although their diversity was lower than the Indian Ocean, due to natural causes including limited recruitment after the last ice age when the Gulf was dry land, severe annual variation of temperature, and extreme salinity. These are simple reefs, dominated by staghorn *Acropora* corals to about 4-5 m depth, then by massive corals (*Porites*, faviids) from 5 m to about 10 m.

**In 1994:** Shipping, particularly tanker traffic for oil transport, had expanded massively with the development of the oil fields, with marked increases in ship-derived pollution. Coastal development had also burgeoned. The substantial nearshore construction, landfill, and oil and civil development have altered much coastal habitat. This applied to seagrass areas as much as to reefs, though the sedimentation affected nearshore reefs in particular. The Gulf War of 1992 damaged coastal habitats but had little obvious effect on subtidal coral cover. Corals remained in similar condition in most areas. There was no coral reef monitoring and minimal awareness of the potential economic and biodiversity value of the coral reefs and the need to conserve them.

**In 2004:** Major coral bleaching events caused by elevated sea surface temperatures (SST) in 1996 and 1998 resulted in massive coral reef damage. In many areas, the entire shallow water staghorn coral zones were killed. Many of these areas have been reduced to shifting rubble fields, with no sign of recovery. This mobile rubble is now making new recruitment more difficult. Some sites are showing signs of recovery, especially in deeper water where there is significant recruitment of faviids of some species not previously especially dominant, such that there appears to be a shift in species dominance on the Gulf reefs. Levels of estimated reef destruction range widely within the region, from a low of 1% in Oman to a high of 97% in Bahrain. The region has established a regional monitoring network and there is rising awareness of the need for effective coral reef management. In parallel there is rapidly expanding coastal development, especially in the Gulf, which is resulting in considerable reef damage and destruction.

**Predictions for 2014:** Forecasts for SST indicate that the shallow *Acropora* reefs will continue to come under increasing temperature stresses and therefore are unlikely to flourish. There may be an increase in coral cover on deeper reefs, with a probable shift in the identity of dominant species in the communities. The recovery on these deeper reefs is conditional on no major increases in SSTs. The reefs in the Gulf of Oman and Arabian Sea are unlikely to change and will probably continue to look like they do now. Coastal Development will continue in the Gulf with increased rates of landfill and dredging, providing more stresses to nearshore reefs, and a continuation of what has happened in the past, creating further degradation. It is hoped that rising awareness of the value of coral reefs will stimulate vigorous monitoring and effective management of the reefs of the Gulf, and a stronger awareness and management of the unusual reefs in the Gulf of Oman and the Arabian Sea.

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#### REVIEWERS

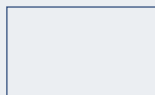
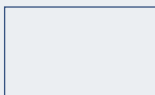
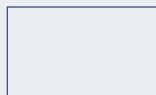
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### **SHEEDVAR ISLAND, IRAN – RAMSAR SITE**

This wetlands site is located in the Province of Hormozgan, 2 km off the eastern tip of Lavan Island and 9 km off the mainland, in the central Persian Gulf. It covers 870 hectares and is surrounded by coral reefs that are in excellent condition. Sheedvar Island also has important nesting areas for the endangered hawksbill and green turtles. Large colonies of breeding seabirds often containing more than 20,000 individuals use the site for nesting.

Sheedvar Island was designated as a Protected Area in 1971 and upgraded to a Wildlife Refuge in 1972. The uninhabited island and its surroundings are owned by the government of Iran and the Department of the Environment manages the area. Although there are hardly any visitors to the island and no recreational activity, there are rangers on the island during the bird-breeding season.

The Hormozgan Provincial Office and Shahid Beheshti University have prepared a poster and booklet about the environment in the province of Hormozgan, with special reference to Sheedvar Island. Some collection of bird or turtle eggs occurs, but far less than previously. Because of the oil terminal on nearby Lavan Island, Sheedvar island is potentially threatened by oil spills and pollution from oil tankers in nearby shipping lanes.

**Ecological Monitoring:** Field surveys of birds and turtles have been conducted during recent decades by the Ornithology Unit from the Department of the Environment.

**Socio-economic Monitoring:** The Island is uninhabited and monitoring is unnecessary.

**Contact:** Department of the Environment, PO Box 5181, Tehran, Iran 15875 (phone: 98 21 321 3322).

**Coral Reefs** are an **unknown** percentage of the natural resources.

**Ecological monitoring** is **occasional**.

**Socio-economic monitoring** is **not planned** as it is not necessary.

## 6. STATUS OF CORAL REEFS IN EAST AFRICA 2004: KENYA, TANZANIA, MOZAMBIQUE AND SOUTH AFRICA

DAVID OBURA, JULIE CHURCH, CAROL DANIELS,  
HASSAN KALOMBO, MICHAEL SCHLEYER AND MOHAMMED SULEIMAN

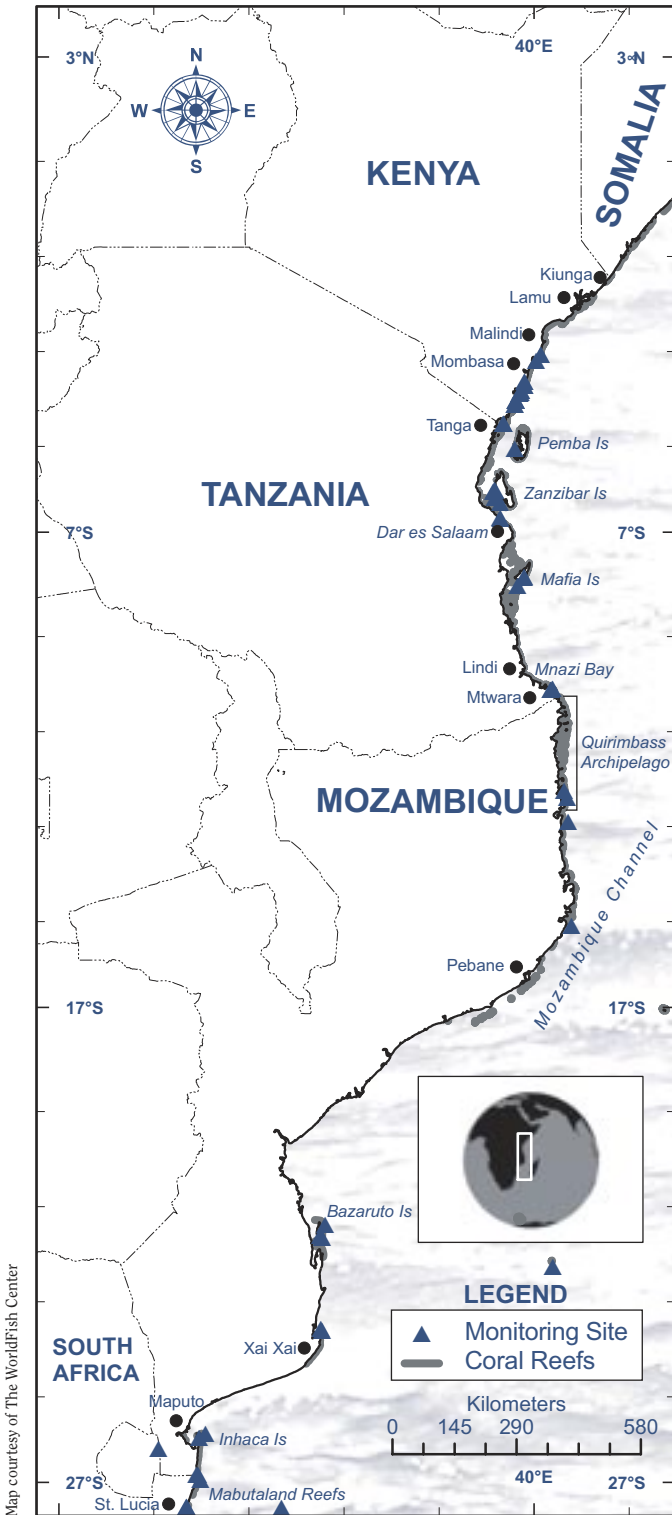
### ABSTRACT

The East Africa coral reef bioregion stretches from Somalia to South Africa, and is interspersed with soft sediment habitats caused by the large rivers flowing into the Indian Ocean. The reefs in the region were heavily damaged by the El Niño Southern Oscillation coral bleaching event in 1998. Since then there has been significant recovery, although this has been patchy and influenced by many other local to regional threats. Coral reef monitoring has been conducted by many national agencies, and local and international NGOs, which have been recently coordinated under a developing Coral Reef Task Force. This combines national commitments through the Nairobi Convention and international support through the International Coral Reef Initiative. In the last 2-4 years, there have been significant improvements in the management of coral reef MPAs due to national and regional initiatives, and greater commitment to increase the area of MPAs, (e.g. in Mozambique) and integrate MPAs into larger networks (e.g. Tanzania). Ecological and socio-economic research on coral reefs is expanding in the region, resulting in outputs that are accessible to broader scientific communities. Socio-economic activities on coral reefs are expanding through a number of research and monitoring programs that are raising awareness of the social dimension and importance of coral reefs to local communities and national economies.

This status report summarises the current status of East African reefs by highlighting current threats, recent developments in management and policy, and case studies. This updates the chapter in the previous Status of Coral Reefs of the World: 2002 report by David Obura and 9 other contributors.

**100 Years ago:** The coral reefs in East Africa were largely pristine, except for localised exploitation and point-sources of pollution around the towns and villages.

**In 1994:** The coastal population had grown to 10-15 million, and subsistence and small-scale fishing were the dominant threats to coral reefs in East Africa, along with some bomb and





beach seine net fishing. There were few MPAs, and little awareness of the need for improved management of coral reefs.

**In 2004:** Major coral bleaching similar to that of 1998 and a coastal population of 22 million are the two primary threats to East African reefs. The bleaching caused the decline of 30% of the region's reefs; the population threats are probably slowing coral reef recovery. On the positive side, the coverage and management is improving in MPAs, as is fisheries management and environmental legislation in all countries.

**Predictions for 2014:** The prognosis for the coral reefs is poor, with a predicted coastal population of 39 million people and the probability that coral bleaching events of similar magnitude to the 1998 event will be repeated. Significant investments in management capacity are needed in all areas, particularly funding to mitigate the likely hardships in vulnerable coastal communities.

## GEOGRAPHY, ENVIRONMENT AND POPULATION

The coast of East Africa covers 40° Latitude from the cool upwellings off the coast of Somalia (10°N) to the cool temperate waters off South Africa (30°S). The major influence is the South Equatorial Current that splits north and south near the Mozambique-Tanzania border. The major reef systems include: the complex barrier and island reef systems of northern and southern Tanzania (800 km long) and northern Mozambique (800 km); the narrow fringing reefs of southern Kenya (200 km); smaller isolated reefs along the southern Mozambique coast (500 km) to South Africa (150 km); and patchy reefs in northern Kenya and southern Somalia (500 km).

There are 22 million people living in the East African coastal region, with the population growing at 5–6% per annum due to births and migration from inland rural areas. Coastal poverty levels are high. The indigenous communities of the coast practised traditional fishing for several hundred years, building up strong cultural and religious ties to the marine environment and the resources. These traditional beliefs are being lost as population densities increase and people move in from other areas. This is resulting in a decline in resource status and a replacement of traditional belief systems and values with more 'modern' beliefs and patterns of use.

*Coral reef and coastline statistics (modified from the UNEP-WCMC World Atlas of Coral Reefs) indicate that most of the coral reefs on the coast of East Africa are under a high level of risk from human activities. The South African coastline with coral reefs in KwaZulu-Natal is 400 km long, and the area estimates for Tanzania and Mozambique are based only on the MPAs. The Reefs at Risk assessment is adapted from the process in Box 460.*

	Somalia	Kenya	Tanzania	Mozambique	South Africa
Marine area (x 1000 km <sup>2</sup> )	828	117	241	565	1,525
Reefs at Risk (%)	95	91	99	76	0
Reef area (km <sup>2</sup> )	710	630	3580	1860	50
Coral diversity (# sp)	308	>300	>370	>370	90
MPAs - Number	0	9	11	5	2
MPAs - Area (km <sup>2</sup> )	0	1,389	1,964	170	2,790

## ECOLOGICAL STATUS OF REEFS

The reporting on the status of the coral reefs in East Africa has been dominated by the damage caused by the coral bleaching and mortality during the El Niño event in 1998 and subsequent recovery. The coral cover recovery has been wide ranging at locations along the coastline and is now at 50 to 100% levels. However, many of the reefs that have shown 'full recovery' to pre-bleaching levels had displayed signs of human induced degradation prior to the bleaching. The apparent rate of recovery was more rapid on these degraded reefs, but only on coral communities that already had lost many slow growing and vulnerable coral species and was instead dominated by opportunistic (*Pocillopora*, *Stylophora*, branching *Porites*) and stress resistance species (massive *Porites*, *Coscinaraea*, *Pavona*). In contrast, the reefs showing the least recovery since 1998 are those that were in better health prior to bleaching. Recovery on these reefs has been affected by chronic and local threats, including over-fishing, crown-of-thorns starfish (COTS - *Acanthaster planci*) infestations and repeated minor bleaching events.

Minor bleaching was reported in northern Tanzania and Kenya during the marine summer of March/April 2003. However mortality was generally low, and in some cases the species that suffered the most bleaching damage in 1998, showed less bleaching than others, for example, *Pocillopora damicornis* and common small *Acropora* species.

A patchy, but widespread increase, in COTS numbers was recorded in 2003 and 2004 in Tanzania and Kenya. The first reports in February 2003 were of aggregations of 10-30 individuals per 10 m<sup>2</sup> spread over 100 m of reef front on an inner patch reef in the Songo Songo Archipelago. In 2004, COTS aggregations appeared on reefs in Tanzania around Unguja Island (Zanzibar), Pemba, Mafia Island, Dar es Salaam, Tanga, and north to Mombasa in Kenya. Some were reported on an isolated reef near St. Lucia, South Africa. COTS numbers have increased a hundred-fold on reefs on the west coast of Zanzibar, from initial densities of 10 per 1,000 m<sup>2</sup> in early 2003, to 10 per 10m<sup>2</sup> in August 2004. These are the largest populations seen around Zanzibar for the last 7 years. There are ongoing attempts to control the COTS with the park staff removing starfish from Chumbe Island Coral Park. Dive operators have also assisted in removing COTS and started a collaborative monitoring program. More than 500 COTS have been collected since April 2004. There has been up to 50% mortality of corals from these COTS outbreaks in some areas, and the damage extends down to 30 m depth. Monitoring is continuing to determine the long-term impacts.

The long-term damage from coral bleaching and mortality are becoming apparent with increased rates of coral reef erosion. Surveys in Mozambique in 2004 showed that some reefs had small decreases in coral cover, attributed to a collapse in the reef framework, while coral diversity and community complexity was still increasing. There are examples of coral tables and plates that died in 1998 subsequently collapsing due to bioerosion. These are now being observed elsewhere in the region, such as southern Tanzania, The Maldives and the Chagos Archipelago.

## ANTHROPOGENIC THREATS TO CORAL REEFS

The most common threat to reefs in East Africa are the effects of fishing, although the specific threat levels will vary at different sites e.g. the relative damage from excess harvesting, destructive gears and migrant fishermen varies. Beach seines and gill nets, and bomb fishing are typical of destructive methods that cause significant damage to habitats, juvenile fish populations and vulnerable species. The high level of effort by migrant fishing on the larger reef systems

*This rating of threats to coral reefs for 3 sample areas in East Africa is based on the experts rating the threat from 1=high to 5=low; 0=no threat. Fishing is the major threat followed by climate change induced coral bleaching.*

Country	South Africa	Tanzania	Kenya
Area	Maputaland	Tanga Coastal Zone Program	Kiunga Marine Reserve
% Degraded reefs	<5	75	30
<b>Threat Rating</b>			
<b>Fishing</b>			
Over-fishing	1	3	1
Destructive Gears	1	1	2
Illegal Fishing	1	3	3
Migrant Fishing	0	1	4
<b>Development Threats</b>			
Coral Mining	0	0	0
Natural Gas/Petroleum	0	0	5
Port Development, Pollution	4	0	4
Population Growth	0	2	5
Tourism Development	3	0	0
<b>Other Issues</b>			
Climate Change	3	2	2
Harmful Algal Blooms	0	5	2
Coral/Other Disease	2	5	2
Crown-of-thorns	1	0	0
<b>Others</b>			
Shipwrecks	1	0	0
Isolation	3	0	0

is rated as a serious problem in places such as Tanga, Tanzania. This poses specific challenges to locally-based management. There has been a resurgence of bomb fishing reported on reefs in northern Tanzania (Dar es Salaam, Tanga) in 2003-04, after there had been successful eradication programs by the Tanzanian Government in the late 1990s. The development of fisheries management practices to mitigate these threats is the primary objective in both places. There is an increasing focus on district-level opportunities for management through collaborative arrangements between local government and communities, and cross-sectoral cooperation among government institutions. Increasing human populations are the major driving force behind the increase in fishing damage. Intensive and growing pressure, combined with high isolation and vulnerable environments, such as in the Maputaland reefs of South Africa, contribute to a high threat level.

### FRINGING REEFS IN KENYA

Coral reefs in Kenya have been monitored by the Wildlife Conservation Society (WCS) since 1987, with a special focus on the response of these reefs to the 1998 coral bleaching and the 2002 fungal disease events. The studies included 7 fished and 5 unfished (protected) reef sites, and showed that the amount of herbivory (grazing on algae) is 20 times higher on unfished than fished reefs. On the unfished reefs the 1998 bleaching mortality resulted in a temporary transition from dominance by hard and soft corals to turf and fleshy algae, then eventually to calcifying algae. There was less change on the fished reefs, where there was a higher cover of algae and sponges after the disturbance, whereas the herbivores reduced the abundance and persistence of macro-algae on the MPA reefs and created space for new coral recruits; however, the annual rates of coral recovery were still low at all sites. Consequently, the positive value of reduced competition with algae and more space for new coral colonization was probably balanced by higher mortality of corals in the MPAs. The reefs in the MPAs are more diverse and complex than the fished reefs, and the lack of fishing pressures probably makes the MPAs less resilient to climate change disturbances. Coral bleaching and mortality are expected to increase with climate change and algae are expected to replace corals when herbivory is low; the amount of change will be influenced by fisheries management and marine protected areas (MPAs). An interesting finding, was that the high temperature bleaching events had less impact on the structure and species composition of back reef sites, where there are normally large variations in temperatures, compared to the sites in more open water, where temperatures are buffered by oceanic waters. The 1998 event resulted in losses of some of the branching species of *Porites* and *Stylophora*, and relative increases in massive *Porites* and *Favia* species; but there were fewer changes in coral cover and community structure on the back reef sites.

In early 2002, there was extensive coral mortality along 600 km of the coastline from Tanzania to Kenya. *Astreopora*, *Echinopora*, and *Montipora* species were severely affected, with *Montipora* being nearly eliminated from Kenyan reefs. *Acropora*, *Platygyra*, *Goniopora*, and massive *Porites* were also affected; however, *Porites* and *Goniopora* rarely died and recovered rapidly, whereas death for most other species occurred within 2 weeks. The coral tissue showed a dull, ash colour and the skeletons were brittle. Eventually the corals appeared to be covered in white calcareous dust. When examined under an electron microscope, the corals that died were covered in fungi; whereas the others had fewer fungi. This may mean that the fungi possibly invaded and killed the corals after they had been weakened by another, unidentified disease. From: Tim McClanahan, Wildlife Conservation Society, Kenya, [tmclanahan@wcs.org](mailto:tmclanahan@wcs.org).

Potential and actual climate change threats are particularly important, but are outside the management control of local and national MPA authorities in Kenya and Tanzania. Nevertheless, East African countries have been active in the search for local opportunities to respond to climate change threats, by focusing primarily on monitoring and improved communication. The examples of Kiunga (Kenya) and Tanga (Tanzania) are pertinent. Participatory monitoring programs have been established with local communities as the primary implementers of coral

reef monitoring. These have stimulated strong education and communication programs with local stakeholders to raise their awareness of the threat of climate change. This has contributed to developing guidelines on management responses to climate change.

Tourism is often cited as a threat to coral reefs. Unmanaged growth of tourism developments and direct-use activities such as uncontrolled scuba diving often results in reef degradation. A recent study in southern Mozambique of the cross-border diving industry with South Africa, however, found that the damage to destination reefs is still minimal; although scuba diving is increasing with no evidence of management. There are recommendations to determine the carrying capacity of reefs and assess these levels with monitoring and research.

### **SOCIO-ECONOMIC STUDIES ON CORAL REEFS**

The development of socio-economic monitoring of coral reef use is a priority activity under the 2004-2005 biennial work program of the Nairobi Convention, within the ICRI Call for Action, and by regional organisations. Training in socio-economic assessment of coral reefs in East Africa started in 2000 with the publication of the GCRMN Socio-economic Manual for Coral Reef Management and the use of the manual in the first training course for MPA and research staff. In early 2003, the Western Indian Ocean Marine Science Association (WIOMSA) hosted a regional workshop to identify socio-economic research and monitoring needs, and opportunities for capacity building. CORDIO (Box p 110) developed a Socio-Economic Monitoring Program (SEMP) in 2002 targeting MPA and fisheries management institutions in Kenya and Tanzania. This is currently operating in 4 sites on the coast, and focuses on collecting data on the occupational structure, resource use patterns and fisher perceptions of conflict among user groups. These data assist local management agencies improve their management effectiveness, and contribute to regional assessments.

More in-depth socio-economic coral reef assessments have been conducted in Tanzania and Kenya. One study, funded by the UK aid agency DFID in 2003, examined fisheries-associated livelihoods and the constraints to their development. A comprehensive socio-economic assessment of the communities and resource use patterns in the MPA was funded through IUCN at the Mnazi-Bay Ruvuma Estuary Marine Park in southern Tanzania in 2004. It also included a detailed study of the occupational structure of villages adjacent to and in the MPA boundaries. This was the first use of detailed socio-economic data on a MPA Management Plan for East Africa. At a broader level, these studies provide detailed baseline data for future assessments of benefits from MPA and fisheries management at the sites, as well as providing reference areas for understanding the dependence of local communities on coral reef goods and services. The importance of local, indigenous knowledge and the intimate dependence of communities on reef resources is being increasingly recognised by MPA managers in the region, and is forming the foundation of new initiatives for conservation (Box p 178).

### **MARINE PROTECTED AREAS**

MPA management in East Africa has been supported through several key regional initiatives in 2003-04, in addition to national MPA agency initiatives. The East African Marine Ecoregion initiative, spearheaded by the World Wide Fund for Nature (WWF), identified priority sites and seascapes for protection, including some that are currently given some protection as national MPAs. The initiative identified 21 priority areas; 8 were ranked as being of global importance, 7 of ecoregional importance, and 6 of sub- regional importance. Particularly notable at the

## LOANS FOR THE FUTURE, AND FOR CONSERVATION – CHOLE, TANZANIA

Hamidu and Nahoda are 16 year old budding entrepreneurs on the small island of Chole, Tanzania. Chole is part of a small archipelago rich with coral reefs, seagrass beds, and mangrove forests, and visited by turtles, humpback and sperm whales, 400 species of fish, and occasional dugong. There are also 15,000 people earning a living from coconuts, fishing and tourism; but life has an easy pace... *Pole pole*, as they say, or 'slowly, slowly'. However, by the early 1990s many islanders' livelihoods were threatened by destructive fishing practices, coral mining, and uncontrolled tourism developments. So villagers asked WWF for help, and with the Tanzanian government, created the Mafia Island Marine Park in 1995.

Since then, they have worked together to eliminate bomb fishing, resulting in a slow recovery of fish stocks. They have also tackled the problem of small-mesh seine nets that catch juvenile fish and damage corals and seagrasses when dragged over the seabed. But replacing the nets and introducing alternative livelihoods is expensive, and the islanders have little money. Thus WWF started an interest-free loans scheme to enable fishers to buy more sustainable fishing gear, and small outboard engines to go out to sea where fishing is better. WWF provided training in running a small business and established 10 village-based savings and loan societies that offered loans to encourage saving. The loans are used to repair boat engines or buy new gear.

"The system is working quite well so far. Most fishers here don't have any experience of owning and maintaining capital assets like fishing gear. The project's aim is to help them develop skills to manage their finances and run a small business - which, of course, they are," explains Jason Rubens, who runs the WWF Mafia conservation support program. "Although the sums involved are relatively modest by outside standards, they do the job and many people here are keen to get involved." New businesses have since started, such as women farming seaweed for carrageenan, and fishermen building fence traps to catch small barracuda and mangrove snapper for the local market. WWF is now investigating the feasibility of a project to grow the local, lustrous bronze coloured pearl oyster for seeding.

After leaving school, Hamidu and Nahoda had little chance of employment, but now they have set up a trial fish-farm with simple 4 x 4 metre cages containing 1,000 juvenile fish which they feed with marine algae. The boys are paid a nominal wage of US\$1 per day to maintain the cages, but when their first harvest is ready at 8 months, they could sell the 250 kg of fish for about 125,000 shillings (US\$125); about 3 to 4 months income for a good fisherman. These are start up loans to provide long-term sustainable livelihood options for the community. The WWF project aims to further the conservation of the coastal systems and species by helping the residents earn sustainable livelihoods through the maintenance of a healthy resource base. From: Peter Denton, Principal Editor, WWF-UK, [pdenton@wwf.org.uk](mailto:pdenton@wwf.org.uk); and Jason Rubens, WWF Mafia Island, [JRubens@wwftz.org](mailto:JRubens@wwftz.org)



national level was the expanded commitment by the Mozambique Government to increase the area protected under MPAs with the declaration of the Quirimbas National Park and the Quilalea Reserve, and a national review of MPA coverage for Tanzania, supported by the World Bank (Box p 180).

Two major tools were developed to assist managers in the region by the IUCN East Africa Regional Office: 'Toolkit for MPA Practitioners in the Western Indian Ocean' ([www.wiomsa.org/mpatoolkit.htm](http://www.wiomsa.org/mpatoolkit.htm)), and 'Management Effectiveness Workbook'. An IUCN Regional Task Force identified the need for more locally accessible and applicable materials for use by MPA managers within the Western Indian Ocean Marine Biodiversity Conservation Project (funded by NORAD). MPA managers and practitioners recognised that many guidelines, training manuals and other relevant materials already existed but were not readily available. They recommended preparation of a Toolkit and Workbook on Management Effectiveness to assist MPA managers and practitioners access existing information on MPA establishment, management and assessment.

The Third Regional Training Course in Marine Protected Area (MPA) Management in the Western Indian Ocean region was held in August 2004, in Malindi, Kenya. The course was run by WIOMSA and attended by 27 people from 7 countries, following earlier courses held in February 2000 in Malindi, Kenya and June 2002, in St Lucia, South Africa. The course provided training in skills, techniques and tools for effective management of MPAs, in order to build a pool of competent MPA managers who would promote an effectively managed system of MPAs in the region, and provide an opportunity for MPA professionals to learn and share experiences on MPA management in the region. The course was for senior staff from existing MPAs in the region and other organisations involved in MPA management, and was based on the 'Training for the Sustainable Management of Marine Protected Areas' manual, and the IUCN tools, the 'Toolkit for MPA Practitioners in the Western Indian Ocean' and the 'Management Effectiveness Workbook'.

As an example of increased capacity and management technology, coral reef research and monitoring efforts in South Africa are focused on assessing the entire coral reef system in order to develop a comprehensive management plan. There is extensive dive tourism on these reefs; much higher levels than in nearby Mozambique. Scientists of the Oceanographic Research Institute in Durban characterised and mapped the reefs of KwaZulu-Natal using underwater digital image analysis, hydrographic surveys and remote sensing techniques. They will make recommendations on the establishment and efficacy of sanctuaries to protect sensitive areas with important concentrations of biodiversity.

## **NATIONAL AND INTERNATIONAL POLICIES AND INSTITUTIONS**

The 'revitalization' of the Convention for the Protection, Management, and Development of the Marine and Coastal Environment in Eastern Africa (the Nairobi Convention, adopted in 1985) has contributed significantly to the increase in activities for coral reef conservation and management. Most recently, regional integration of coral reef activities in East Africa and the Indian Ocean Island countries was given a boost through a renewed call for action and the formation of the regional Coral Reef Task Force under the Nairobi Convention (the Regional Seas Convention for the Protection of Marine and Coastal Environments). Initially established at the Conference of Parties of the Convention in 2001, the Task Force held its second meeting during the COP meeting in Madagascar, in July 2004, where the need to strengthen and



## A NETWORK OF MPAs IN TANZANIA

Tanzania declared its intention to increase protection of its seas to 10% by 2012, and 20% by 2025 to participants at the World Parks Congress in Durban in 2003. This new network of MPAs would include more coral reefs of Tanzania than the 1.9% that is totally protected now. A study which identified options to develop a national MPA system using support from the World Bank is the basis for a new World Bank and GEF project - Marine and Coastal Environmental Management Project. This is intended to support marine and nearshore policy reforms and policy implementation to improve the quality of life of coastal populations and maintain the integrity of coastal and marine resources of national, and international, significance. A series of subregional MPA networks was proposed, based on the multi-stakeholder visioning exercise coordinated by WWF's Eastern African Marine Ecoregion Program to include the main high biodiversity areas as follows:

1. The northern Tanga Region: a transboundary area with Kenya including reefs and fisheries managed under Collaborative Management Areas Plans and implemented jointly by villages and the Districts. This includes Maziwe Island Marine Reserve, managed by Pangani District for the National Marine Parks and Reserves Unit;
2. Pemba Island: the northern island of Zanzibar with only one MPA, the Misali Island Conservation Area (a no-take zone and a low use zone), managed jointly by the Misali Island Conservation Association (MICA) and the government;
3. Unguja Island: the main island of Zanzibar with 3 MPAs: Chumbe Island, a small no-take MPA with management by the private sector; the Mnemba Island Conservation Area and the Menai Bay Conservation Area are larger MPAs where regulated fishing is allowed and managed by the Department of Fisheries with a private lodge and local villages;
4. Dar es Salaam-Bagamoyo: the Dar es Salaam MR System with 4 designated Marine Reserves managed as a single system;
5. Latham Island: an offshore island south of Dar es Salaam with significant coral reefs and seabird populations;
6. Rufiji-Mafia-Kilwa-Songo Songo complex: Mafia Island Marine Park; potentially a World Heritage designation, and proposed for a Ramsar site with the mangroves of the Rufiji Delta; and
7. Mtwara District: including the multiple-use Mnazi Bay-Ruvuma Estuary MP; a potential transboundary conservation area with Mozambique.

An important addition to achieve the 10% and 20% goals will be the development of an MPA network for offshore and oceanic waters. These potential subregional networks of mixed MPAs will require the development of new MPAs to ensure that the sites are systematically linked. New research is needed on bleaching and recovery patterns on reefs to help understand larval dispersal and current patterns. Socio-economic data and information are also needed, notably fishing patterns (there is close correlation between high biodiversity areas and high fishing effort) and plans for tourism development (coastal areas are top priority in the national Tourism Development Plans). From Sue Wells, WWF Tanzania.

coordinate national task forces was identified as a primary goal. Potential options for funding of improved coordination were investigated.

## CONCLUSIONS

East African countries are making significant national commitments to conserve and manage coral reef resources because of their importance in supporting coastal populations. However,

*This table summarises the current status of the reefs in East Africa and makes predictions for the future. These are based on estimates from East African experts, however, it is acknowledged that there are large gaps in knowledge about coral reefs in the region and extrapolations were necessary from the limited amount of long-term monitoring data.*

	Kenya	Tanzania	Mozambique	South Africa	REGION
1. seriously damaged or totally destroyed –	10	10	10	0	7.5
2. strong recovery since 1998	30	30	30	NA	30
3. high risk: clear damage -	30	20	20	10	20
4. medium risk: moderate damage -	30	30	10	30	25
5. low risk: healthy and relatively stable	0	10	30	50	22.5

1. 90% of the corals are gone and unlikely to recover soon

3. 50 to 90% loss of corals and likely to join category 1 in 10 to 20 years

4. moderate signs of damage - 20 to 50% loss of corals and likely to join category 1 in 20 to 40 years.

NA. not applicable, as there were no losses in 1998.

this is occurring as the coral reef resource baseline is declining due to over-exploitation linked to increasing population levels, and climate change threats derived from an expansion of the global economy. There are insufficient data to fully understand the threats and set management priorities, e.g. for over-fishing, destructive fishing or coral bleaching. Substantial management interventions will be necessary to relieve the worst impacts of change on vulnerable coastal populations, and to contribute to possible long-term recovery of the coral reefs.

**100 Years ago:** While there is no quantitative information from this time, coral reefs in East Africa would have supported subsistence fishing of small indigenous communities, and the urban populations of the main Swahili towns and settlements. Impacts were probably minimal and localised, as local populations had adequate marine and terrestrial (agricultural) resources to exploit. Therefore the reefs were in near pristine condition with only small examples of damage near towns and losses of some species e.g. turtles and dugong.

**In 1994:** The coastal populations of Mozambique, Tanzania and Kenya had increased dramatically to approximately 10-15 million. The expansion of subsistence and small scale fishing was still the dominant threat to coral reefs in East Africa, with only the most remote areas of northern Kenya, southern Tanzania and northern Mozambique showing minimal exploitation and damage. These areas were exploited by migrant fishing, and the use of destructive techniques (bombs, seine nets) was common. Around some major population centres, coral reef fisheries had been depleted for more than 20 years, and pollution of coastal waters from urban centres

was evident. There were few concerns expressed by governments about the status of the coral reefs and management of existing MPAs was focused on tourism benefits rather than resource conservation.

**In 2004:** The coastal populations have increased to 22 million people, with ever increasing pressures on coral reefs and their resources. The massive coral bleaching of 1998 which caused declines in approximately 30% of the region's reefs, further exacerbated the continuing increases in fishing pressure. While there has been notable recovery of corals in some areas since 1998; the recovery is estimated at about 30-50%, however, many depleted reefs have shown no recovery. Management efforts are increasing in all countries, with significant commitments being made to increase the area of Marine Protected Areas, improve fisheries management and implement environmental legislation. There is also a sense of cooperation between countries along East Africa to develop networks of MPAs to ensure the availability of coral reef larvae.

**Predictions for 2014:** At a current growth rate of 6%, coastal populations will be nearly double at 39 million in 10 years time, exerting even greater pressure on reef resources. A repeat coral bleaching event similar to that of 1998 is likely. Pollution around major urban centres will increase, and the growth of secondary towns will add to the number of sites with significant point-source pollution threats. The area of marine habitats under strict management will increase in all countries, possibly approaching the regional goal of 20-30%. However, without significant investments in capacity in all areas, the effectiveness of these efforts may be limited, resulting in greater declines in the regions' reefs.

## RECOMMENDATIONS

The recommendations for improved management expressed in the Status of Coral Reefs of the World: 2000 and 2002 reports are as valid in 2004 as they were then. These called for: improved monitoring and adaptive management; the incorporation of socio-economic information into management and policy development; and streamlining regional networks, collaboration and support. Implementation of these recommendations is underway in numerous ways in the region. Therefore the current recommendations focus on improving and institutionalising current trends, including:

- Strengthening and institutionalising cross-sectoral and between-country collaborations in all areas of management, legislation, policy and science. This should include improving management within MPAs and in adjacent un-managed areas;
- Strengthening cooperation in ecological and socio-economic coral reef monitoring and the sharing of data and information;
- Increasing national and local support for management through greater allocations from governments, and investments by the private sector; and
- Increasing funding support from external agencies to fill the widening gap between resources and required actions to mitigate the degradation of reefs in the region.

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**ICRAN**

### **MALINDI AND WATAMU NATIONAL PARK AND RESERVE, KENYA**

The Malindi and Watamu National Reserve encompasses Watamu and Malindi Marine National Parks, the first marine parks established in Kenya in 1979. These MPAs encompass coral reefs, seagrass beds and mangroves and used by nesting turtles and several marine mammal species. The ICRAN project focuses on coral reefs, developing management action strategies and small-scale infrastructure, a review of socio-economic issues and current management plans, and development of a training and education network. Monitoring equipment has been upgraded and small-scale infrastructure has been renovated and constructed, including community boat storage and repair facilities, and offices and community shops. Conflict and maintenance data, visitor and fisheries catch statistics have been compiled and a biophysical profile developed. A community mangrove boardwalk was constructed in Watamu, and bird hides rehabilitated for ecotourism to demonstrate sustainable mangrove uses and help generate funds for local schools.

The Malindi Resource and Training centre facilities were upgraded and receive more than 120 visits from schools and universities every year. In 2004, the Centre hosted the Reef Check/ West Indian Ocean Marine Science Association 'Training of Trainers for Voluntary Monitoring of Coral Reefs', and the training course for regional MPA managers. Malindi will continue as a centre for awareness raising and training. Despite early challenges, this project has resulted in a consultative partnership between local communities and managers. The focus on management effectiveness has generated momentum within Kenya Wildlife Service, and managers now collect information for an initial MPA assessment.

**Ecological Monitoring:** Ecological monitoring is undertaken in Malindi by the KWS, the Wildlife Conservation Society, Coral Reef Conservation Project, and the CORDIO project, but MPAs are also initiating their own basic monitoring. Information on benthic cover, coral and fish diversity, coral recruitment, fish abundance, predation, herbivory, and density of invertebrates is collected annually. There has been some recovery from the 1998 mass mortality with new coral recruitment and re-growth. There are also indications that more rapid recovery, higher species diversity and higher fish abundance occurs in no-take zones than adjacent fished areas.

**Socio-economic Monitoring:** The draft management plan needs updating. During its development, considerable socioeconomic data were collected, and fisheries catches monitored. A socio-economic assessment of Malindi boat operators highlighted gaps in business management and investment practices.

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**Coral reefs** are 10% of the natural resources.

**Ecological Monitoring** is effective.

**Socio-economic Monitoring** is planned.






**ICRAN**

### **CHUMBE ISLAND CORAL PARK EDUCATION PROGRAM, ZANZIBAR – ICRAN FUNDED PROJECT**

Chumbe Reef Sanctuary covers 30 ha of fringing reef with about 50% coral cover, 20% seagrass beds, and 30% sand flats. The reef is one of the most pristine in the region, with more than 370 species of fish and 200 species of reef-building corals, representing about 90% of all reef fish and corals in East Africa. Chumbe Island Coral Park (CHICOP) was established in 1991 as a privately funded coral reef conservation project that designated Chumbe Island and its western fringing reef into a fully managed no take area and became an officially gazetted MPA in 1994. CHICOP conducted baseline surveys, built a visitors' centre and a small eco-lodge, trained local fishermen as park rangers, produced a Management Plan for 1995-2005, and raised awareness of government and community through an Advisory Committee.

A few years ago, these coral reefs were under serious threat from: overfishing; destructive fishing practices; pollution; and sedimentation, which led to a decline of fish landings and increasing destruction of the formerly pristine reefs. Public awareness about the need for sustainable management of these precious resources was urgently needed, but coral reef ecology was poorly covered in the school syllabus. Field excursions were rarely organised, and few children had the opportunity to visit a coral reef. School children, particularly girls, do not normally learn how to swim and snorkel. To raise awareness and knowledge of reefs, CHICOP conducted school field trips and a course for secondary students and their teachers. Guided by park rangers, the children learned firsthand about Marine Biology and Environmental Protection. Recently, CHICOP has conducted school excursions (600 children and 60 teachers), facilitated a stakeholder meeting, provided training of Rangers, negotiated to integrate this course into all secondary schools and teacher training, and conducted public evaluation of the project to further include all local stakeholders.

**Ecological Monitoring:** Park rangers have been stationed on the island since 1992 and produce weekly reports on coral bleaching and storm and anchor damage. They are now ReefCheck trained to complete systematic ecological monitoring including surveys of corals, fishes, and invertebrates.

**Socio-economic Monitoring:** Socio-economic monitoring includes research on short-term and long-term benefits to local communities. A recent study established that local fishermen have reported 'spill-over-effects' (increased catches in adjacent fishing grounds), contributing to their acceptance of the no take area.

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**Coral reefs are 50% of the natural resources.**

**Ecological Monitoring is occasional.**

**Socio-economic Monitoring is occasional.**

**ICRAN**

### **DAR ES SALAAM MARINE RESERVE, TANZANIA – DEMONSTRATION SITE**

North of the commercial city of Dar es Salaam, there are marine reserves around 4 islands: Mbudya, Bongoyo, Pangavini, and Fungu Yasini. Their coral reefs, mangroves and seagrass beds are jointly managed as the Dar Es Salaam Marine Reserve System (DMRS). In the past, the reserves have been overexploited by fisherman and physically damaged by unregulated tourist activity and dynamite fishing. To help manage the park, the Marine Parks and Reserves Unit (MPRU) has developed a collaboration whereby community members are certified to become Honorary Rangers (HR). The HRs, many former beach boys whose status has been raised with an education and job qualification, improve services for visitors by keeping the beaches clean, providing first aid and information, confirming that visitor fees have been paid and helping with park surveillance. Since the introduction the number of paid fees has increased dramatically, making the scheme self-financing. The HRs are responsible for giving informative tours at the visitor centres and have been trained in coral reef monitoring, snorkeling, rescue and life saving together along with other community members, park staff, and students.

The ICRAN project has provided the MPRU with a boat and engine, GPS equipment, binoculars, demarcation buoys, radios and handsets to strengthen the communication and enforcement activities. There have been several arrests and convictions and dynamite fishing has been significantly reduced. In addition, 2 visitor centres have been constructed at Bongoyo and Mbudya which provide outreach materials and information. Community members and MPRU staff have visited other MPAs in the region, to observe their conservation management strategies in order to establish the best practices at DMRS. Initial community engagement for the DMRS General Management Plan, has involved 3 awareness meetings on effective community participation in the sustainable use of marine resources. As a result of these meetings, community fishers have been selected as ambassadors for the park.

**Ecological Monitoring:** Reef fish biomass and species diversity have increased over the past four years, mainly as a result of improved enforcement of reserve regulations. However, coral cover is now over 95% *Montipora*, whilst other species have decreased in abundance. There are few lobsters, ornamental and edible molluscs, and sea cucumbers, primarily due to over-fishing. Non-commercial starfishes have declined while coral-eating crown-of-thorns-starfishes (COTS) are on the rise.

**Socio-economic Monitoring:** There has been very little work on the stakeholder interactions with the resources of Dar es Salaam Marine Reserve. The key stakeholders have been identified and their attitudes and interests have been assessed as well as the potential socio-economic benefits relevant to the sustainable use of marine resources.

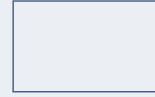
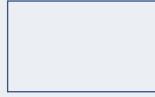
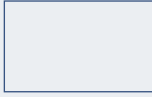
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**Coral reefs** are 30% of the natural resources.

**Ecological Monitoring** is occasional.

**Socio-economic Monitoring** is occasional.





## **KIUNGA MARINE NATIONAL RESERVE, KENYA – MAN AND THE BIOSPHERE RESERVE**

Kiunga Marine National Reserve is a MPA covering 250 km<sup>2</sup> in northern Kenya, near the border of Somalia. It was formed in 1979 and together with the terrestrial Dodori National Reserve became a UNESCO Biosphere Reserve in 1980. The reserve includes a chain of about 50 offshore islands and coral reefs in the Lamu Archipelago, running parallel to the coastline and adjacent to Dodori and Boni National Reserves on the mainland. The islands vary in size from a few hundred square metres to larger than 100 hectares and provide important nesting sites for migratory seabirds and serve as a refuge for dugongs. The area is also known for having the world's largest breeding populations of roseate terns, and is a key feeding ground for many migrant species.

Kiunga Reserve is of local and global importance for its habitat, species and physical and biological processes. Mangroves, seagrass beds and coral reefs act as homes, nurseries and spawning grounds for populations of fishes, crustaceans, invertebrates and mammals. It is a key nesting site for the 3 species of turtles found in Kenya, the Green, Hawksbill and Olive Ridley.

**Ecological Monitoring:** Monthly catch assessments are made in each village around the reserve and provide valuable data to management authorities and local fishermen. Catch data are complemented by fish surveys and coral reef assessments. The Kiunga Marine National Reserve team, in collaboration with the Wildlife Conservation Society, carried out the first coral reef survey in 1998, just before a coral reef bleaching event. This survey allowed researchers to determine the rates of recovery of affected coral reefs that have also been recently protected from heavy fishing. There are also projects to assess methods to restore degrading reefs. A local community turtle-monitoring program, supported by Kenya Sea Turtle Conservation Committee, was established in 1997.

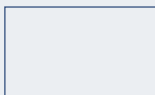
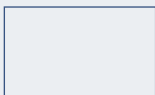
**Socio-economic Monitoring:** An environmentally friendly handicraft industry has been created to generate income for households and tidy up the beach. Rubber flip-flops washed onto the beach are collected and carved into a variety of handicrafts including key rings, necklaces, belts and bags. The income goes directly to the community and to funding long-term management strategies for the area.

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**Coral reefs** are 50% of the natural resources.

**Ecological Monitoring** is effective.

**Socio-economic Monitoring** is effective.



**GREATER ST LUCIA WETLAND PARK, SOUTH AFRICA - WORLD HERITAGE SITE**

The entire north-east coast of Africa is connected by a chain of coral reefs (covering 239,566 hectares) that extends into the Greater St Lucia Wetland Park World Heritage Site. This site includes the Ramsar site Turtle Beaches/ Coral Reefs of Tongaland. The coral reef comprises 3 reef complexes: the Kosi Reefs or Northern Complex; the Sodwana Bay reefs or Central Complex; and Leadsman Shoal or the Southern Complex. The Northern and Southern complexes both lie within highly protected sanctuaries, which limit recreational diver use. The Central Complex is the largest and most accessible, receiving about 100,000 dive visits per year. The reefs are favoured by sport-fishermen and they have become increasingly popular for sport diving.

The major coral reefs in South Africa all are a part of the Greater St Lucia Wetland Park and the combined research and monitoring results have contributed towards the development of a management strategy for the central area. The reefs constitute one of South Africa’s most diverse and valuable, yet scarce and fragile ecosystems. They have especially rich biodiversity (over 125 coral species and almost 400 fish species have been identified) and tremendous potential for ecotourism. There are also 32 species of marine mammals including whale sharks and dolphins. Agriculture, road construction, and development along the upstream area of St. Lucia has impacted the marine environment. Oil pollution and active dredging of the St. Lucia estuary are ongoing management concerns and other potential threats.

**Ecological Monitoring:** Monitoring began in 1991 to provide baseline information on the ecology and management of the reefs. The Oceanographic Research Institute has conducted coral reef research and monitoring throughout the Southwest Indian Ocean. Research subjects include: the species composition of corals, sponges and tunicates; community structure of corals and associated organisms on representative reefs; the condition of the reefs; and effective management to ensure sustainable reef use. The presence of coral-eating gastropods and COTS is also monitored. These programs are in collaboration with the University of Cape Town and the University of Tel Aviv.

**Socio-economic Monitoring:** The governments of South Africa, Mozambique, and Swaziland have initiated the Lubombo Spatial Development Initiative and a regional plan and management framework are being prepared.

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**Coral reefs are 40%** of the natural resources:  
**Ecological Monitoring is effective.**  
**Socio-economic Monitoring is planned.**

## 7. STATUS OF THE CORAL REEFS OF THE SOUTH WEST INDIAN OCEAN ISLAND STATES

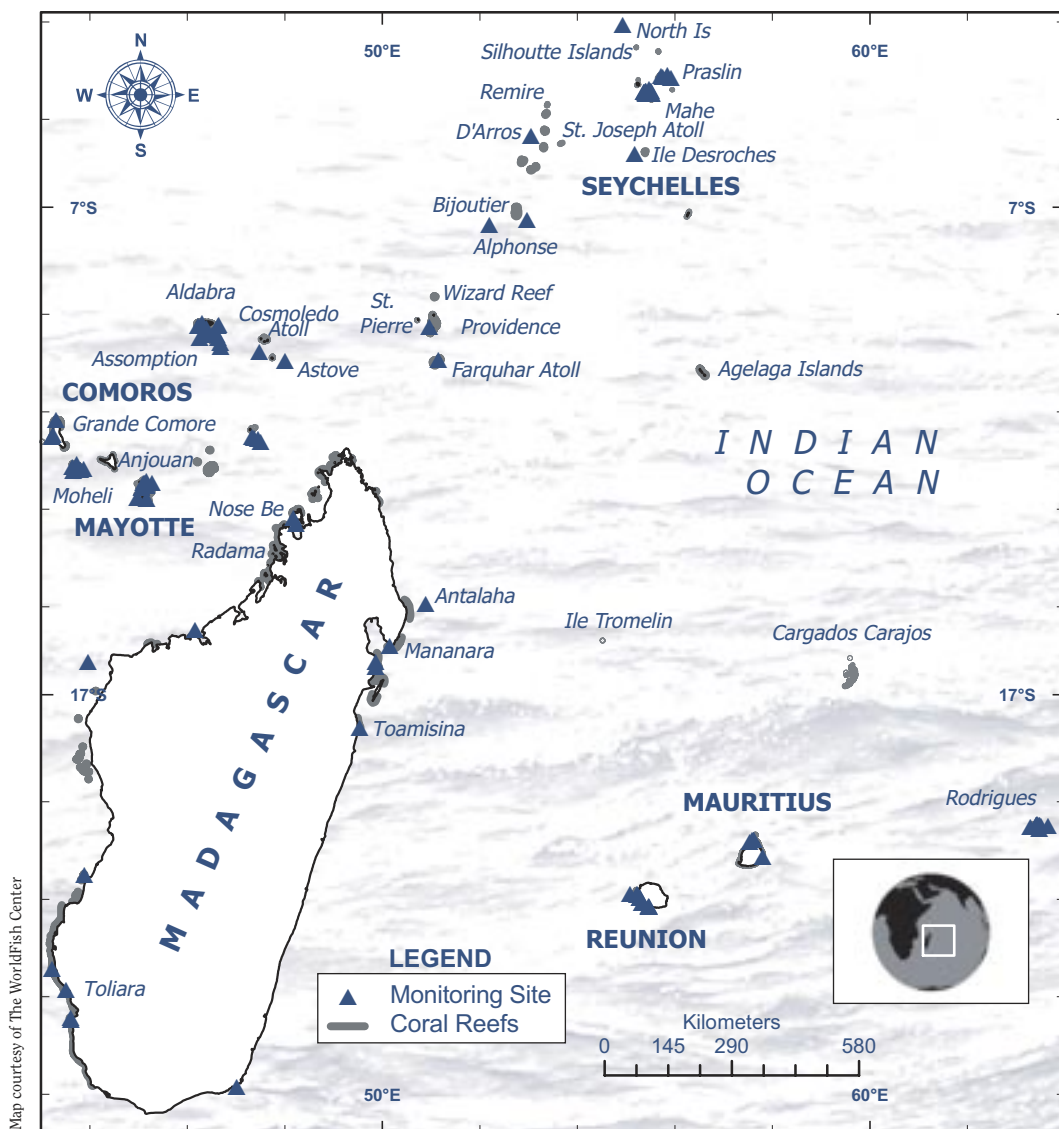
SAID AHAMADA, JUDE BIJOUX, LIONEL BIGOT, BRUCE CAUVIN, MEERA  
KOOONJUL, JEAN MAHARAVO, SABRINA MEUNIER, MARYLENE MOINE-PICARD,  
JEAN-PASCAL QUOD AND REX PIERRE-LOUIS

### ABSTRACT

Some coral reefs of the countries of the South Western Indian Ocean are showing recovery from the coral bleaching event of 1998 that reduced live hard coral cover on many reefs to less than 5%. However, recent bleaching events and subsequent mortality of the new recruits are impeding this recovery. Some exceptional sites are proving to be highly resilient to the bleaching damage, while at other sites, anthropogenic stresses including excessive sedimentation, pollution and trampling are compounding the effects of natural disturbances, such as cyclones, and increasing reef degradation. There is considerable effort to increase the capacity to manage and to improve decision making. It is encouraging that certain states are reporting increased resistance of *Acropora* to coral bleaching, as these coral species are a critical component of the 3-dimensional structure of reefs, and for creating complex habitats for fish and other reef species. The region is described as a biodiversity 'hot spot', with a large number of endemic species. The number of monitoring sites in the region has continued to increase, with the inclusion of some less accessible sites, such as Tromelin, Juan da Nova, Europa (France) and Cosmoledo, Assumption and Aldabra (Seychelles). These sites have been surveyed within the last 2 years to improve the knowledge of the status of the coral reefs of this region over a larger geographical range. Socio-economic evaluation of coral reef resources has been carried out in some states within the last 2 years. The management of MPAs is being strengthened to increase the effectiveness of conservation in the face of a predicted increase in frequency of coral-bleaching events.

**100 Years ago:** Most of the reefs in this region were pristine with very few adverse impacts other than cyclones that were common during the summer months below about 10 degrees South. There were low levels of exploitation of fish and other commercial species, however, turtles and tortoises were harvested extensively.

**In 1994:** Many reefs were still relatively healthy, apart from areas where there were ports and unregulated coastal developments. Reef management was largely undeveloped and there was a general lack of awareness and political will for reef conservation.



**In 2004:** Most coral reefs have changed since the 1998 bleaching. Coral cover has declined significantly on many reefs, especially in shallow areas. There are now signs of recovery in many sites, though the rate is relatively slow at most sites. At other sites there has been recent mortality that has slowed the recovery process considerably. However, there have been marked increases in awareness of the need for coral reef management and conservation, and all countries have established active monitoring programs to assist in environmental decision making.

**Predictions for 2014:** If management does not improve and there are repeats of the recent climate-related stresses, it is predicted that most reefs in the region will have less than 20% live coral cover by 2014. Many species of corals and fish will be locally extinct due to losses from coral bleaching and over-exploitation of some fish and invertebrate species. The reverse

situation is likely on most remote reefs, if management proves effective, and the predicted stress from global climate change is not so severe.

## INTRODUCTION

Coral reefs in the 5 states of the South Western Indian Ocean Island Node collectively cover an area of 5270 km<sup>2</sup>. Although few studies have been conducted to assess marine biodiversity, there are indications that this region is rich in biodiversity and endemic species. The reefs are particularly important in these small countries where their economies are heavily dependent on tourism and fishing. Furthermore, the reefs are very important for coastal protection, especially from the frequent strong cyclones south of 10° South.

The coral reefs around the larger islands are usually under considerable human pressures, with increasing human populations and coastal development. These stresses have been exacerbated by frequent coral-bleaching events. The more isolated reefs, such as those of the Southern Seychelles, remain relatively healthy and untouched by land-based anthropogenic input. However, these sites have also been affected by coral-bleaching events and are threatened by over-fishing and poaching of sharks. Since the 1998 mass coral-bleaching event, the region experienced smaller damaging episodes in 2002 and 2003. Interestingly, the *Acropora* species have been less affected relatively in the recent events in some areas, whereas they were the first affected in 1998. This may indicate a degree of acclimatisation to bleaching events, or there may have been selection of species more resistant to warm-water bleaching. There is increasing evidence that a change in the content of algal symbionts may convey more resistance (Box p 25). In many other sites, however, there was high mortality of new recruits.

Monitoring started in most states after the 1998 coral bleaching with the formation of the regional coral reef monitoring network. This network functions as the GCRMN South West Indian Ocean Island States node and is currently being supported by a GEF medium-sized grant and the European Union through the Indian Ocean Commission (COI). Support from the GEF has been extended for an additional 18 months but will cease in June 2005. The regional network is strengthening national monitoring capacity and raising awareness and educating local populations. NGOs, private groups and companies have established their own monitoring programs in the region. Privately managed islands in the Seychelles, such as at D'Arros and North Island, have their own monitoring programs and longer term monitoring has been done at Aldabra by the Aldabra Marine Program.

The frequency of monitoring has increased in each country from once to twice per year, and some countries are initiating socio-economic studies, in parallel with reef monitoring, to assist management. The COREMO II database, based on the AIMS ARMDDES database, was created in the region to assist countries with data storage and analysis. The focus is on GCRMN and Reef Check recommended methods, with the possibility of entering data at the species level for corals and reef fishes. COREMO II has been recognised by the GCRMN as the model for distribution to all nodes around the world and Version III is currently being developed.

## BIODIVERSITY

The region is characterised by many endemic species and is recognised as a region of high biodiversity. There are 320 species of hard (scleractinian) corals including 7 endemic species; *Pectinia africanus*, *Acropora roseni*, *Pocillopora indiania* and *Horastrea indica* are regional

endemics, whereas *Montipora kellyi*, *Pocillopora fungiformis* and *Stylophora madagascarenis* are country endemics found only on the south coast of Madagascar.

Extensive surveys of the inner granitic islands of the Seychelles have found that 69% of all previously-recorded coral genera and 88% of the families still occur in this area after the bleaching losses of 1998. An increase in reported coral species compared to surveys in 2003 indicates that the biodiversity of the reefs is slowly recovering after the initial fear that many species had become locally extinct in 1998. However, coral bleaching is still an important risk factor that could reduce coral diversity in this region if the predictions of an increase in frequency and severity of coral bleaching events are correct.

Mauritius also has a diversity of corals, with 159 hard (hermatypic) coral species and more than 310 fish species. In the central South Western Indian Ocean, there are 316 species of algae, 8 seagrass species, 351 sponges, 71 octocorals, 55 sea anemones, 165 caridean shrimps, 22 sea spiders, 376 gastropods, 200 bivalves, 150 echinoderms and more than 400 species of reef fish. This list focuses on the larger specimens and many smaller species remain to be discovered.

Degradation of coral reefs, due to bleaching and other stresses, will ultimately affect other reef organisms, such as fish, because of a loss of reef structural complexity and the number of available habitats. Sea turtles are also at risk, especially Hawksbills (*Eretmochelys imbricata*), which feed on reef organisms.

## RESOURCE USE

Coral reef fishing is one of the main uses of reefs in the region. Fishing usually involves hooks and lines, and a diversity of traps, which differs from country to country. There is also an active sea cucumber (holothurian) fishery in some states, which has expanded over the past 10 years. This fishery is collapsing in Madagascar and there are hatchery trials to produce juvenile sea cucumbers to replenish reef stocks. Scuba collection is now banned to limit access to the deeper reefs. In the Seychelles, an FAO sponsored study is assessing populations of the exploited species to develop a management plan. In 2003, 129,421 sea cucumbers were harvested with an export value of US\$370,000. A precautionary approach is being used now and the number of fishing licences has been capped at 25. Sea cucumber fishing in the Comoros is relatively new, however, demand for harvest licences is increasing. The octopus fishery is well developed in the Seychelles, Rodrigues (Mauritius), Comoros and Madagascar, and there is some collection of shells and corals for the curio trade in most countries. Coral and coral sand are extracted for construction on some islands, however there are increasing efforts to control any damaging effects. Mauritius phased out the sand and rock mining industry in 2002, after it was shown to have caused damage in the lagoon. Many other countries also are banning the extraction of sand from the beach.

The most important non-extractive use of coral reefs in the region is in tourism and recreation. These countries of the South West Indian Ocean have economies that are heavily dependent on tourism and are marketing themselves as eco-tourism destinations. More than 50% of people who visit the Seychelles either snorkel or dive, and there are about 700,000 visitors per year to Mauritius. Most of these visitors are seeking fun from the sea and sun and supporting the second largest sector of the economy. The tourists, plus the local population of 1.2 million, make Mauritius one of the most densely-populated countries of the region.

## A RAPID MARINE BIODIVERSITY ASSESSMENT OF THE CORAL REEFS OF NORTHWEST MADAGASCAR

A Marine RAP survey in early 2002 found high levels of biodiversity at 30 coral reef sites from Tsarabanjina to Nosy Hao, northwestern Madagascar. The highlights were:

- Corals: 318 species recorded, including 9 new species and many range extensions; this greatly exceeds previous estimates which predicted that there were 340 species in the western Indian Ocean;
- Molluscs: 525 species found, which is similar to areas of the 'Coral Triangle' centre of marine diversity in Southeast Asia;
- Reef Fishes: 463 species including 2 new damselfish species; the total reef fish fauna for Madagascar is about 752 species based on past records;
- Reef Fisheries: about 55 reef fish species are targeted by local fishers, especially species of Serranidae, Lutjanidae, Caesionidae, Lethrinidae, Haemulidae, and Scaridae;
- Reef Condition: Most reefs were in relatively good condition, with the most frequent damage from local populations of COTS;
- Community Issues: The community liaison team found that the main concerns of fishermen in 15 villages were declining fish stocks, lack of economic resources, and migrant fishermen.

The data from this survey supported the inclusion of the Nosy Hara Archipelago by the government of Madagascar in a proposed MPA expansion announced at the World Parks Congress in September 2003. The survey was under joint financing from the United Nations Trust Fund (FAO subcontract UNTS/MAG/001/GEF no PO 1081138) to Conservation International, with the researchers from the Centre National de Recherches Océanographiques, Centre National de Recherches sur l'Environnement, Institut Halieutique et des Sciences Marines, WWF Madagascar and CI – Madagascar as well as experts from the Australian Institute of Marine Science and the Western Australian Museum. Contact: Harison Randrianasolo, Conservation International, Antananarivo, Madagascar, randrianasolo@conservation.org

## STATUS OF CORAL REEFS

### Comoros

**Status of reef benthos:** Moya (Anjouan) and Itsandra (Grande Comoros) are amongst the most frequented spots by tourists to the Comoros, therefore they warrant sound management and conservation. Coral recovery is occurring after major losses in 1998. The reefs at Itsandra lost most of their corals, but they are being rapidly recolonised by new recruits. This has reduced the amount of available bare surface on the reef from 45% in 2003 to 37% in 2004. The new coral growth has increased the live cover from 36% in 2003 to 42% in 2004. Algal cover in Moya has dropped from 61% in 2003 to 8% in 2004, thereby creating more space for new coral growth (35% in 2003 and 52% in 2004). Cover of dead corals remains at 37%.



Biodiversity is high, especially in the coral families of Acroporidae and Faviidae at Ouani (Anjouan Island); however coral cover remained constant between 2003 and 2004. The growth of the more fragile branching and table *Acropora* corals warrants extra protection for this site, as it remains one of the healthiest and structurally complex reefs in the Comoros.

Conversely, the reef at Moroni (Grande Comoros) has low diversity but relatively high coral cover (53%), dominated by *Porites lutea*. In contrast to Ouani and Moroni, the reefs at Mitsamiouli (Grande Comoros) and Bimbini (Anjouan) are under constant pressure with unregulated trampling and fishing with small mesh nets resulting in over-exploitation, such that even the smallest fishes are rare.

There are numerous signs of damage on the Bimbini reef, especially a proliferation of sea urchins (*Echinometra* sp.) and macro-algae (*Sargassum* sp.). Live coral cover has decreased from 24% in 2003 to 18% in 2004. Overall, regeneration of corals is continuing at most sites, with coral cover returning to its pre-bleaching level, especially at Itsandra in Grande Comore and Moya in Anjouan. However, coral cover is declining at Mitsamiouli in Grande Comore and Bimbini in Anjouan, whereas there has been no net change in cover at Wani and Moroni.

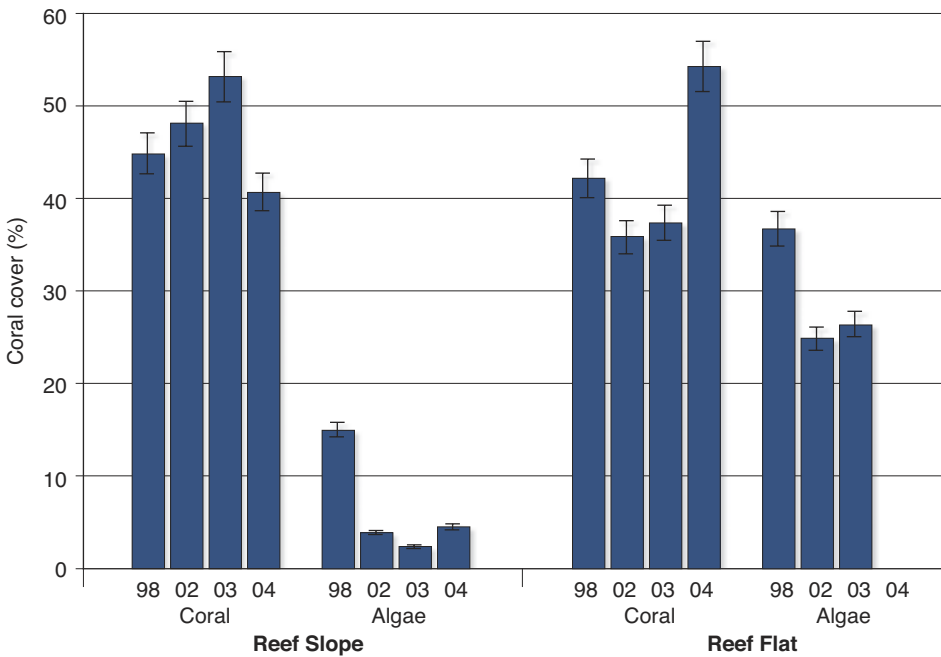
Significant regeneration has occurred on the reefs around the island of Moheli – notably at Sambia, Walla, Candzoni and Mea – with 70% live coral cover on the reef slope at Walla in 2004. The large increases in coral cover and the overall health of the reef are a direct result of conservation programs being implemented in the Moheli marine park. The geomorphology of the coast has helped protect the reefs, as there is a large underwater plateau, small islets and shoals, which buffer the reefs against the large waves from the strong southeast winds. This protection promotes coral recruitment and regeneration.

### **Madagascar**

**Status of reef benthos:** There are 2 monitoring sites with 4 stations in the north-west sector of Madagascar; the fringing reefs of Dzamandjar, and the reef of Tanikely. In 2004, the hard coral cover on the reef slope at Dzamandjar declined from previous years to 40.8% with 37.6% non-living coral or rock. In contrast, the reef flat at Dzamandjar showed an increase in coral cover to 39.5% with 22.3% algae. At Tanikely, there has been a significant drop in coral cover on the reef slope between 2003 and 2004; to display the lowest cover since 1998.

There is 45.7% coral cover on the Foulpointe reef slope in the eastern sector, but there is increasing sediment input – although apparently this has not damaged the corals. Coral cover continues to increase slightly on the reef flat and slope since 2002, despite the corals on the reef flat being smothered by sediment. Additionally, there has been a continuous increase in soft coral cover on the reef slope, which is probably a response to the high sediment load. Other sites in this sector were not monitored in early 2004 because of cyclones, but they will be monitored in late 2004.

There has been no significant change in coral cover between 2003 (48.3%) and 2004 (49.8%) at Grande Recif de Toliara in the southwest sector. However, the area of bare rock and rubble increased from 6.6% in 2003, to 25.3% in 2004; possibly a result of the strong tropical cyclones that hit Madagascar. These storms caused severe sediment problems, due to re-suspension and high sediment run-off from the land.



*Live coral cover on the reef-slope and reef-flat of Dzamandjar, north western Madagascar from 1998 to 2004 has remained relatively stable between 36% and 55%, while there is considerable cover of macro-algae on the reef-flat, possibly indicating lower populations of grazing fish and/or nutrient enrichment.*

**Status of reef fish:** The most reliable information on the reefs of North-West Madagascar including Tanikely, is from the Conservation International Rapid Assessment Program of 2002. There was a dominance of algal grazing fish (Acanthuridae) and triggerfish (Balistidae, especially *Rhinecanthus aculeatus*) indicating coral reef degradation on the Foulpointe reef. This matches current anecdotal information, with a lack of predators (Lutjanidae, Lethrinidae) due to high fishing pressure on this reef. Monitoring of coral reef fish populations started in 2004 at 2 monitoring stations; Foulpointe reef (east side) and the Antrema reef in Madagascar. The strong cyclones in early 2004 prevented monitoring at other sites.

On the East coast at Antrema, the dominant families were Lutjanidae and Haemulidae. The fringing reef of Antrema still has major reef fish stocks, in spite of extensive turbidity problems from the Betsiboka River.

Stock assessment on the North West coast, shows commercial fish stocks are still healthy in this part of Madagascar. The estimated biomass of target fish ranged from 3.11 ton/km<sup>2</sup> to 1255.85 ton/km<sup>2</sup> (mean 170.12 ton/km<sup>2</sup> ± 5.53) at 10-13m depth and from 12.44 ton/km<sup>2</sup> to 2184.49 ton/km<sup>2</sup> (mean 270.73 ton/km<sup>2</sup> ± 9.43) in shallow areas. These data indicate that there is a greater biomass of target fish in shallow areas, with the total target fish biomass ranging from 3.11 ton/km<sup>2</sup> to 1720.17 ton/km<sup>2</sup> per site.

The highest concentration of target fish species, both overall fish density and estimated biomass, was at Tanikely, near Nosy-Be; because this reef is protected from fishing. The sites at Tsarabanjina and Ankarea in the Mitsio archipelago (northwest of Nosy-Be) showed the next largest fish populations.

Several CI-RAP studies	Mean total Biomass (ton/km <sup>2</sup> )
Raja Ampat Is. Indonesia, 2001	208.97
N.W of Madagascar 2001	182.30
Milne Bay Province, PNG, 2000	125.56
Togian Banggai Is. PNG 2000	66.49
Busuanga, Culion Is. Philippines, 1998	16.94

(Source: Allen et al. 2000; La Tanda, 1998; Ingles, 1998; Maharavo, 2002)

### Reunion

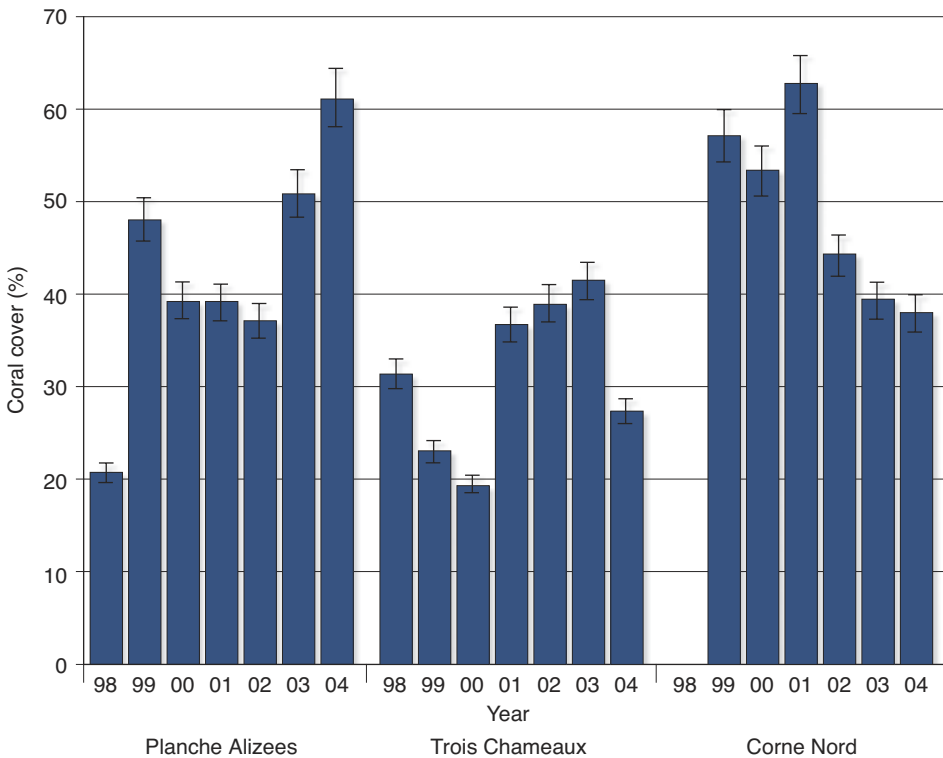
**Status of reef benthos:** Live coral cover has decreased from 41% in 2003 to 27% in 2004 on the reef flat at Trois-Châteaux (Saint Gilles/ La saline sector), while algal cover increased 3-fold since 2003. This is predominantly due to a local bleaching event in 2004 that resulted in high mortality in *Acropora formosa*, the most common coral species on that reef. Of the 27% cover of live coral, 14% bleached in 2004 including most of the *Acropora*. The second most abundant coral species, *Montipora circumvallata*, did not bleach, and the cover has not changed since 2003. The number of bio-eroding echinoderms (*Echinometra mathaei*) had multiplied 3 fold from 30 to 100 individuals per 250 m<sup>2</sup> – a direct correlation with increased algal cover.

The increasing trend of coral cover at Planch’Alizés (a disturbed site) has continued from 2003 to 2004 with an increase of 10%. Most of the increase is from opportunistic and robust species, such as *Montipora circumcallata* and *Pavona spp.*, which are common at this site. The amount of bleached coral was very low; less than 1% of the total live coral. There was a small increase of 3.3% in *Acropora* coral cover at this site from 2003 to 2004; this site escaped damage from the bleaching event of 2003. This may suggest that these corals are slowly adapting to higher temperatures, or there is natural selection favouring colonies with an increased ability to cope with higher temperatures. *Pavona* and *Porites* species were unaffected by the 2003 coral-bleaching event.

There was coral bleaching at the Corne Nord (Saint Leu Sector) in February 2004, with about 100 m<sup>2</sup> of compact finger-like *Acropora* colonies bleached on the outer reef-flat. Surveys in April showed that 90% of the colonies had completely recovered, although corals on the inner reef-flat had started to bleach. *Acropora hemprichii* was the most heavily-affected species and constituted 90% of bleached corals; monitoring is ongoing because this site is becoming famous for its high-bleaching resilience. There was a decrease in non-living cover, and an increase in algal cover from 2003 to 2004. Therefore, there has been no significant change in live coral cover between 2003 and 2004 on the reef at Corne Nord, despite nearly half of the hard corals being bleached. Species richness continues to decrease at this site and is linked mostly to a recent decrease in non-*Acropora* corals – probably due to natural and anthropogenic pressures.

There was extensive bleaching on the reef-slope and outer reef-flat of La Varangue at St Leu in 2004, with 30% of corals bleached. Additionally, there was a reduction of 28% in coral cover between 2003 and 2004, with an increase of algae growing on dead *Acropora*. This loss was probably linked to the exceptional events of mid 2003, with large winter swells and major low tides, which killed many *Acropora* colonies, but not corals from the genus *Pavona*. There was 75% bleaching of the dominant species (*Acropora muricata*) with smaller percentages being killed. It is now expected that the coral cover will increase from its 2004 level (42%). Other reef flat stations were similarly affected.

On the external reef slope at St Gilles, there has been a progressive decrease of live coral cover since 2000. This trend is due to damaging natural factors (repeated cyclones, heavy rains, and small, local and chronic bleaching events) and not regarded as alarming when compared with other coral reefs of Reunion. There was a constant increase in coral cover on St Leu reef slopes, to the current level of almost 80% cover, mainly composed of robust *Acropora* (*A. danai*, *A. robusta*) and table *Acropora* (*A. hyacinthus*). The impact of cyclones 'Dina' and 'Harry' and minor bleaching in 2002 and 2003 have not affected this area, which continues to be stable and healthy.



*These three graphs illustrate changing patterns of live coral cover at different locations on Reunion. Coral cover on the reef-slope of Planche Alizees has increased over these 6 years to more than 60% cover, whereas cover on the reef-flat of Trois Chameaux has been relatively stable, although at a lower level of around 30%; and on the reef-flat of Corne Nord, there has been a decline in coral cover. These changes reflect natural events, rather than direct human pressures.*

**Status of coral reef fish:** There was an increase in herbivorous fish biomass at Trois-Châteaux in 2004, and a decrease in the biomass of invertebrate grazers; this is consistent with the benthic observations. The abundance of predator species was again low. There was a 4-fold increase in herbivorous fish biomass between 2003 and 2004 at Planch Alizés, but a similar low abundance of predators. Similarly, the biomass of herbivores increased 2 fold at Corne sur nord of Saint-Leu between 2003 and 2004. Acanthurids (especially *Acanthurus triostegus*) were prevalent, and correlated with an increase in algal cover on this site in 2004.

**Synthesis:** After 5 years of consecutive monitoring at the reference sites of Saint-Gilles/La Saline (1998/2003) and Saint-Leu (1999/2003), there is a reliable trend in the coral and fish populations. Coral cover on most reef-flats was stable between 2000 and 2002, but has decreased in 2003 and 2004 after local, but exceptional, bleaching events in 2003 were followed by large winter swells and extreme low tides. *Acropora* species were particularly damaged, whereas the more opportunist species appear to be more resistant. Coral cover on the reef slopes has increased, indicating that the local bleaching events had minimal effect. These trends will be followed in 2005; but they indicate the need for regular and long-term monitoring of the environment to distinguish between 'natural' events like bleaching, and human impacts from dumping, fishing, intensive use by visitors and coastal development.

### Mauritius

**Status of reef benthos:** Coral cover dropped from 48% in 2002 to 37% in 2003, with a parallel increase in rock and rubble from 46% to 56%, and algae to 8% on the back-reef at Trou aux Biches, north west Mauritius. The dominant corals were the branching *Acropora formosa* and table *A. hyacinthus*. Coral cover decreased on the reef slope from 50% in 2003 to 38% in 2004; dead substrate went from 45% to 57%; and algal cover was 4%. These same *Acropora* species also dominated the reef flat at Albion where there was an increase in coral cover from 46% in 2003 to 54% in 2004, and a sharp decrease in macro-algal cover from 31% in 2003 to 6% in 2004. However, on the fore-reef slope, the coral cover decreased from 50% in 2003 to 31% in 2004; dead substrate increased from 12% to 65% and algal cover from 35% to only 0.4% in 2004. In the south east at Blue Bay Marine Park, coral cover remained stable at 91%, of which 59% was mainly table *Acropora* sp. Both algal cover and dead substrate were low.

After the global coral bleaching event of 1998, the reefs in Mauritius suffered a minor bleaching event in 2003 and 2004. Coral bleaching was observed in the lagoonal patch reefs, reef-flats and reef slopes and studied at four sites: Ile aux Benitiers, Belle Mare, Poudre d'Or and Albion. Branching and table *Acropora* species were mostly affected on the back reef, while massive *Porites* were affected in the fore-reef. In 2003, bleaching of corals was observed by mid February, and by June, 95% of the bleached corals had recovered, while 2% were recovering, and 3% had died. In 2004, the trend was similar to the past year, but coral mortality was slightly higher.

**Status of coral reef fish:** Damselfish were dominant at most of the sites, followed by butterflyfish and surgeonfish. *Stegastes* species were present in large numbers at almost all sites, and sea-urchins were abundant at some sites, resulting in degradation of the reef structure. Triggerfish and large predators were entirely absent from all stations.

**Status of physical environment:** Sea water quality parameters were generally within the Government Guidelines for Coastal Water Quality Requirements at all the sites in 2003 and 2004

## Rodrigues

**Status of reef benthos:** Coral cover on reef slopes ranged from 14.3% at Passe Armand, to 45.5% at Grand Bassin, whereas dead coral covered 1.2% at Riviere Banane, and 6.3% at Passe Armand. There was between 3.4 and 6.1% bleached coral at these sites. Soft coral cover varied from less than 2% at Passe Armand and Riviere Banane, to 11.5% at Grand Bassin, and macro algae were minimal at all sites except for 12.7% cover at Riviere Banane. *Acropora* species were dominant at Grand Bassin and Riviere Banane (35.3% *Acropora* vs. 10.2% non-*Acropora*, and 18.3% vs. 10.6% respectively), while non-*Acropora* corals were more prevalent than *Acropora* at Passe Armand (9.8% vs. 4.6%). Grand Bassin was the most diverse station, with 5 non-*Acropora* and 3 *Acropora* morphology types recorded, and branching *Acropora* clearly dominating with cover of 25.5%. There were 7 different coral types at Riviere Banane (4 *Acropora* and 3 non-*Acropora*, with table *Acropora* dominating at 13.3%) and 6 at Passe Armand (4 non-*Acropora* and 2 *Acropora*).

The reef flat stations at Grand Bassin, Trou Blanc and Passe l'Ancre had very similar coral cover; range 14.1% to 14.9%. Riviere Banane and Passe Armand had much lower coral cover (6.6% and 3.8% respectively). The mean cover of dead coral was very high at Passe l'Ancre (17.2%), but averaged only 4.3% at Trou Blanc, and was not recorded at any other station. No bleached corals were observed at Passe l'Ancre, but elsewhere, there were between 0.2% (Riviere Banane) and 9.4% 'Passe Armand' bleached corals. Soft coral was absent from Grand Bassin and Passe Armand, but was the dominant benthic feature at 38.8% cover at Trou Blanc. Macro-algae were minor components on the bottom at Passe l'Ancre, but the cover was 14.0% and 17.2% at Trou Blanc and Riviere Banane respectively. Bare rock and dead coral cover ranged from 23.2% at Trou Blanc to 85.0% at Passe Armand.

The cover of *Acropora* species was twice that of non-*Acropora* corals at both Grand Bassin and Passe l'Ancre (9.6% vs. 4.5% and 9.9% vs. 5.0%, respectively). The average cover was approximately equal at Trou Blanc (7.5% non-*Acropora* vs. 7.1% *Acropora*). Non-*Acropora* dominated coral cover at Riviere Banane and Passe Armand, with no *Acropora* recorded at the latter site.

**Status of coral reef fishes:** Damsel-fishes were the dominant group at each reef slope station, with 48/250m<sup>2</sup>. The mean number of surgeonfish ranged from 12.3/250m<sup>2</sup> (Riviere Banane), to 26.7/250m<sup>2</sup> (Passe Armand), and between 3.3/250m<sup>2</sup> (Riviere Banane) and 7.0/250m<sup>2</sup> (Grand Bassin) of butterflyfish were seen on average. *Chaetodon trifasciatus* dominated the butterflyfish counts at all sites. Mean numbers of parrotfish varied between 36.7/250m<sup>2</sup> (Riviere Banane) and 62.3/250m<sup>2</sup> (Grand Bassin). Immature parrotfish were most numerous at all sites, although a relatively large school of *Scarus scaber* and *S. sordidus* was seen at Riviere Banane. Triggerfish and large predators were entirely absent from all stations, indicating high fishing pressure.

A similar pattern occurred on the reef-flat, with a dominance of damselfish at Grand Bassin, Trou Blanc and Passe l'Ancre. The mean abundance ranged from 71.7/250m<sup>2</sup> to 130.0/250m<sup>2</sup> individuals per transect at these stations, although surgeonfish were the most prevalent group at Riviere Banane and Passe Armand (72.3/250m<sup>2</sup> and 31.7/250m<sup>2</sup> individuals, respectively). Species composition differed from that on the reef slopes, however, relatively high numbers of *Stegastes* species were present at all sites except Grand Bassin, and *Dascylus aruanus* dominated the southern sites of Trou Blanc and Passe l'Ancre. Butterflyfish were present



in much lower numbers (ranging from 0/250 m<sup>2</sup> at Riviere Banane to 3.3/250 m<sup>2</sup> at Grand Bassin). Parrotfish numbers were low at Trou Blanc (a mean of 4.0 individuals per transect) but increased to 62.0/250m<sup>2</sup> on average at Grand Bassin. Again, small, immature individuals dominated counts, but numbers were augmented by *Scarus sordidus* at Passe l'Ancre and *S. sordidus* and *S. ghobban* at Grand Bassin. No triggerfish or predators were recorded at any station of the reef slopes.

### Seychelles

**Status of Coral Reefs - The Inner Islands:** There was an average of 10.2% live hard coral cover on the 48 reef sites surveyed in early 2004. This shows moderate levels of recovery from only 3% mean coral cover in November 2000 at 22 sites. The coral recovery has been steady, with statistically significant increases every year since 2000. The recovery has continued, even though there were minor coral bleaching events in early 2002 and 2003, which resulted in a slowing, or slight reduction, of coral growth and cover. Many new coral recruits were killed in mid 2004 on several sites in the granitic Seychelles; however, the positive growth trend continued after the bleaching events. Available anecdotal information suggests that this recovery is 20-30% of the coral cover prior to the 1998 losses.

There were significant differences in the rates of coral recovery between the inner granite islands and the true coral reefs. On the reefs, coral cover has increased from a mean of 3.4% in 2000, to 6.3% in 2004, with a mix of periods when cover declined or remained unchanged during bleaching in 2002 and 2003, and periods of stronger recovery. In contrast, coral cover on the granite-base reefs has increased steadily every year since 2000, from a mean of 2.5%, to the current cover of 14.2%; an almost 6-fold increase in hard coral cover. There was also slower growth during the coral bleaching of 2002 and 2003, but growth was still more vigorous. Coral cover on the reef sites (typically fringing reefs) was lower than those on granitic reef sites: reef sites  $6.3 \pm 0.6\%$ ; granitic sites  $14.2 \pm 0.5\%$ .

**Status of Coral Reefs - Southern Atolls:** In May 2003, live coral cover around Aldabra Atoll ranged from 3% to 58% in shallow water, with the very low values shallower than 10 m depth. Below 10 m depth, cover improved, though Acroporids were low at all depths. Cover varied from 0.4% to 52% in deeper water, with total coral cover (soft and hard corals combined) increasing substantially over 4 years at 4 shallow-water sites and 2 deep-water sites. The increase in mean of total live coral cover at all sites between November 1999 and May 2003 was 11.7% in shallow water, and 4.9% in deep water; giving an annual increase of 3.3% and 1.4% respectively. The hard coral component in shallow water was 0.3%, but in deep water there was a decrease of 1.4%. The maximum increase in hard coral cover was 4% in shallow water and 3% in deep water at one site. The changes in coral cover were dominated by soft corals, especially the genus *Rhytisma* which forms an encrusting mat 2 - 4 mm thick. Dead coral cover and algal cover have barely changed, except that there has been a considerable increase in coralline algae, especially in shallow water.

The survey of Cosmoledo Atoll by CORDIO and the Island Conservation Society in late 2002 showed that bleaching-related mortality had been very severe, with only a few *Porites* colonies surviving at all reef slope sites down to about 10 m. Mortality of corals in the lagoon apparently exceeded 95%, but was less severe in channels and passes where there were vigorous water exchanges. Large colonies of *Acropora*, which once dominated shallow water coral communities, are now rare. *Porites* and faviids were among the best survivors. Most small corals in shallow



water had settled since the 1998 bleaching event. Coral cover was 20-25% at 20 m, and coral diversity was considerably greater than in shallow waters.

Coral diversity was high with 120 species from 15 families and 45 genera recorded. The families with the most species were the Faviidae (34 species) and Acroporidae (32); and at the genus level, *Acropora* (19), *Montipora* (12), *Favites* (9) and *Porites* (8). The high diversity of *Acropora* was surprising given the major bleaching mortality suffered by this genus. Species diversity was noticeably low in the *Favia*, *Fungia*, *Pavona*, *Millepora*, *Alveopora*, and *Goniopora*, which may be due to the isolation of the atoll or bleaching-related mortality. Some species typically common in the western Indian Ocean reefs were absent or rare, particularly *Galaxea fascicularis*, *G. astreata* and *Goniastrea pectinata*.

The average number of new coral recruits ranged between 5 and 6.7 m<sup>-2</sup> on the reef slope and 6.8 m<sup>-2</sup> in the lagoon. On reef slopes, recruitment was greater at 20 m than 10 m. Faviids were most common at 20 m, while pocilloporids dominated at 10 m. The species composition of recruits differed from the pre-bleaching adult community. In the lagoon, *Porites* and *Fungia* recruits were most common, while previously dominant acroporids were rare. On the slopes, faviids and *Pocillopora* dominated the recruit population. The large reservoir of surviving adult corals at depth seems to be assisting recovery, but a shift in species composition is underway. The prognosis for Cosmoledo's reefs is good, provided further warming does not kill colonies surviving in deeper water.

**Status of Coral Reef Fish:** The Seychelles Marine Ecosystem Management Project 'coral reef program' found significant differences in the abundance of 24 of the 29 fish types between the west and east islands of the inner island group between 2001 and 2004; 18 had significantly higher abundances in the east around Praslin, La Digue and their satellite islands; and 6 groups were higher in the western region around the island of Mahe and its satellite islands. These results suggest that there are different pressures on the fish populations in the two regions, because habitat types and conditions are similar across the two regions. The differences between key target species of snappers, groupers, parrotfish and triggerfish, as well as butterflyfish, suggest that human activities are the major reason for the differences.

The granite reefs have a much greater 3-dimensional structure than the fringing reefs, and this appears to explain why 23 of the 29 fish types were more abundant on the granite reefs (16 categories) than on carbonate reef (7 categories). Moreover, 7 of 29 fish categories were more abundant inside protected areas than outside, especially butterflyfish, parrotfish, wrasses, snappers and groupers. These include some of the main target species of the local trap fishers, thereby demonstrating that the MPAs are offering some protection.

The Seychelles National Coral Reef Network report that fish populations have been relatively stable over the last year; however, the abundance of algal grazing surgeonfish was low at all sites – probably because high levels of sediment have smothered their preferred diet of turf algae.

Since 1999, an average of 210 fish species has been recorded each year around Aldabra Atoll. The survey in 2003 counted 203 species at densities of 1,864 per 100 m<sup>2</sup>, and most fish were in the 1 – 10 cm size category. At nearby Assumption, 100 fish species were recorded at densities of 2,430 fish per 100m<sup>2</sup> and at St. Pierre 128 fish species were recorded at densities of 8,715 fish per 100m<sup>2</sup>.

At Cosmoldeo Atoll, the survey conducted in 2002 recorded more than 200 species of fish. Acanthurids were common, large and medium sized groupers were recorded at all sites, and snappers and emperors were frequently sighted. Obligate coral eating fish, *Chaetodon trifascialis* and *Chaetodon trifasciatus*, were rare even at depths where coral cover was greater. No sharks were seen.

### **STRESS AND DAMAGE TO CORAL REEFS**

The damage to coral reefs in the South West Indian Ocean region is from natural and man-made disturbances. The natural threats include cyclones (cyclone period November – February), coral bleaching (occurring during the warmest months from February to April) and COTS outbreaks that occur very rarely. A COTS outbreak was recorded in Mauritius in 2003 on a patch reef between Ile aux Cerfs and the east coast. Dry acid (sodium bisulphate) was used to eliminate them and has proven very effective, with no damage observed on other marine organisms. The man-made threats are mainly from extensive coastal development, land-based pollution, sewage outfalls and anchor damage.

There is substantial agriculture on some of the island states, with the result being high nutrient concentrations and large volumes of sediments are often carried by water running off the land – especially during cyclones. In Madagascar, fishermen walk over reef flats dragging nets which cause substantial damage to corals. Similarly, bomb fishing in the Comoros causes substantial damage. Coral trampling occurs in all states.

Mining of coral sand and coral for construction has caused considerable damage to some coral reefs in the region, with most states implementing stricter legislation and licensing to control exploitation. Mauritius has banned coral sand mining. Anchor damage to corals is also considerable, and many countries are installing mooring buoys (e.g. Reunion, Mauritius) in heavily used and ecologically sensitive areas.

### **POTENTIAL FUTURE THREATS TO CORAL REEFS**

The major potential threats to coral reefs in the region are natural disturbances such as cyclones, further coral bleaching events, outbreaks of coral predators and diseases (which may all be linked to human activities; Chapter 1. p 67). Other anthropogenic activities include destructive fishing, over-harvesting, pollution, introduction of invasive species, and non-environmentally friendly coastal development.

### **MANAGEMENT**

#### **Mauritius**

The Mauritius Government (Ministry of Fisheries) is improving coral reef conservation by banning bomb fishing, and sand and coral mining. They have proclaimed new MPAs with supporting regulations and supporting long-term monitoring of coral and fish communities. Eight new MPAs were proclaimed in June 2002, including two Marine Parks and the remaining 6 proclaimed as Fishing Reserves. Marine Park staff now enforce the regulations in Blue Bay Marine Park (353 ha) and Balaclava Marine Park (485 ha). Monitoring is showing that the coral reefs in these marine parks are in good condition. Public-awareness campaigns have been launched on the importance of coral reefs and mangroves, and a mangrove re-planting program has started.

### **Comoros**

The government has made rational management of the environment and coastal zone a priority after recognising widespread degradation of the ecosystems of the Comoros. The increased political will is expressed in a national environmental program and an environmental action plan, with projects to strengthen environmental management. The regional environmental program of the Indian Ocean Commission (COI) was one of the first major projects, with the objective of integrated management of the coastal zone, including socio-economic and ecological assessments. The goals are to support capacity building and establish an information system to facilitate decision making. Pilot studies have started to determine the feasibility of integrated coastal management plans at local levels. Another plan addresses the problem of marine ecotoxicology.

The biodiversity conservation project financed by the GEF has commenced, reinforcing the environmental management plan and environmental action plan. The principal outcome of the project will be the creation of a pilot national park managed under an agreement of cooperation with the local community. The first MPA was the Marine Park of Moheli created in 2001 by Presidential Decree. This park is on the island of Moheli, between Miringoni and Itsamia, and has a total surface area of 40,360 ha. The objective of the park is to ensure the conservation and sustainable use of the coast and the marine biodiversity, notably the natural resources and the development of ecotourism activities. A second MPA is proposed in the south east of Grand Comores (between Salimani Hambou and Chindini) for the conservation of the coelacanth and its marine and coastal environment.

### **Madagascar**

The Ministry of Environment, Waters and Forests of the Malagasy Government has adopted regulations to protect of the natural environment, including marine areas. Madagascar has signed and ratified several international conventions, and is increasing the protected areas to preserve the natural patrimony of the country. One program is the Environmental Program Phase III, which includes the protection of coral reefs as one of its objectives using finance by the World Bank. Monitoring of pollution and environmental degradation on coral reefs has been implemented in the northwest and southwest of the island to assist decision making in response to problems.

### **Seychelles**

A national environmental management plan for the country was formulated in 1990 and revised in 2000 and is used to guide environmental management. The implementation of this plan is overseen by a multi-sectoral steering committee. Additionally, Seychelles has a National Biodiversity Action Plan that guides marine and terrestrial biodiversity conservation. There are 6 Marine National Parks, 3 Special Nature Reserves in the Seychelles occupying an area of 413 km<sup>2</sup>, and 4 Shell Reserves. Most of these protected areas started in the 1970s and are playing an important role in marine environmental conservation and the tourism industry.

The Seychelles Marine Ecosystem Management Project ended in early 2004, and produced an extensive coral reef survey of the inner granite islands. Many of the sites continue to be monitored, and the data are proving very useful in making informed decisions. A Marine Protected Area System Plan has also been developed to improve integration of MPA management in the Seychelles. Many islands are holiday resorts with environmental programs that include regular monitoring of coral reefs, sea birds and sea turtles. It is important to note that all development in the Seychelles requires the completion of an Environmental Impact Assessment.

## CONCLUSION AND RECOMMENDATIONS

Most coral reefs in the region are slowly recovering from the damage caused during the 1998 mass coral bleaching event. However, several new bleaching events on Reunion and the Seychelles in 2003 and 2004 have reversed some of this recovery and served as a warning that the 1998 bleaching was not an isolated event. There is a need for increased efforts to reduce the amount of anthropogenic impacts on coral reefs in the region. A first step could be to strengthen awareness and educate to include a better informed population on the need for coral reef conservation. Increased coverage, better representation and improved management of MPAs would ensure better protection for the more diverse and resilient reef sites. Biodiversity programs should be initiated to explore diversity on the less studied reefs of the region and the training of local para-taxonomists to ensure long-term interest in the program and its longevity. There is a need to have increased collaboration in monitoring between the SWIO node and the East African node, and the CORDIO program. Likewise individual coral reef monitoring programs within countries should be linked to the greater regional coral reef monitoring program and results communicated as widely as possible. These individual programs are encouraged to increase the number of sites monitored and the amount of active network members. Voluntary Reef Check networks should be encouraged as a means of sensitising the local communities and tourists, and to act as an early warning system of large scale events, such as coral bleaching and toxic algal blooms. There should be better integration of results from socio-economic studies in the management of coral reefs and MPAs in the region. The regional network should also encourage collaboration with other international and regional programs such as the Census of Marine Life and the Global Invasive Species Program, as many of them have important coral reef components. New sources of funding to support the Regional Coral Reef Monitoring Program in the SWIO should be sought to allow the continuation of coral reef monitoring in the region when the GEF support ends in June 2005.

## CONCLUSIONS

One hundred years ago more than 95% of reefs in the region could have been described as pristine with limited damage in areas around ports and anchorages. Ten years ago in 1994, coral reefs from the region were still in a relatively pristine state. However, reef sites close to areas of urbanisation and uncontrolled coastal development were being affected by development. Presently, most coral reefs in the region are at very high risk with the biggest threat being coral bleaching events. It is expected that the coral cover will probably be less than 20% by 2014 if the predicted frequency of bleaching events occurs, with those countries in the north of the SWIO being the most affected.

## RECOMMENDATIONS

- There is a need to increase reef awareness programs to reach a larger proportion of the population.
- Increasing the area of protected areas is recommended. The conservation of coral reefs would be improved: if more representative sites were included within MPAs; if protected areas were strategically located to protect the more diverse and resilient reef sites that are making a disproportionately large contribution to the recovery of already damaged reefs; and if there is improvement in the management of existing MPAs.
- There is a need to initiate biodiversity programs to explore diversity on the less studied reefs of the region.

- Volunteer coral reef monitoring networks should be encouraged as a way of getting more people involved in reef management and raising awareness of the issues facing coral reefs.
- Results from socio-economic studies should be incorporated in the management of coral reefs and MPAs in the region.
- The regional network should increase collaboration with other global or regional programs such as the Census of Marine Life program and the Global Invasive Species Program.
- Funds should be sought to ensure continuity of the regional coral reef monitoring program when the GEF project comes to completion in June 2005.

## REVIEWERS

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## ACKNOWLEDGEMENTS

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**ICRAN**

### **ST. ANNE MARINE PARK, SEYCHELLES – ICRAN DEMONSTRATION SITE**

St. Anne National Marine Park, which is 5 km east of Port Victoria (the capital of the Seychelles), was designated in 1973 to conserve the exceptionally rich and varied marine life of the area. The Park has coral and granitic reefs, extensive seagrass beds and is an important nesting ground for sea turtles. Eco-tourism is the main activity and there are organised glass-bottom boat, snorkeling and diving trips. In 2003, there were more than 10,000 non-resident visitors to the park. The park has 3 different zones:

- Underwater Diving Zones (areas to be used by glass bottom boats and for snorkeling);
- Protected Zones (areas with reefs, seagrasses, turtle nesting beaches); and
- General Use Zones (for picnics, boating, swimming and similar leisure activities).

Potential threats include future bleaching events and the introduction of invasive marine species. Oil spills from the many tankers that use Port Victoria are also a potential threat. Coastal reclamation on the east coast of Mahe may have caused damage to the park in the past. Existing legislation is being updated to improve enforcement effectiveness and a series of consultative meetings were organised in 2004 to involve more stakeholders in park management. A project to mark the boundaries of the park is underway (ICRAN funding). More marine parks rangers and research officers have been employed to conduct biological and socio-economic research.

**Ecological Monitoring:** Coral reef monitoring is conducted twice a year, and there are plans to increase it to improve management effort. There is also monitoring of turtle nesting (turtle and track counts, size measurements). A beach monitoring program initiated in 2003 focuses on seasonal fluctuations of the beach profile and a number of specific research projects are investigating factors affecting recovery of reefs impacted by bleaching events. Data from 4 consecutive years is available to guide management planning.

**Socio-economic Monitoring:** Previous lack of human resources resulted in incomplete socio-economic monitoring. New research staff together with the availability of new socio-economic manuals have resulted in plans for a long-term socio-economic program. Indications of park visitors are determined from park entry fees paid by foreign tourists and boat mooring fees. In 2003, the recreational value of the park was estimated to be more than US\$18 million and the fisheries benefit as a source of adults and larvae to other reefs outside the marine park boundaries was estimated at approximately US\$ 0.2 million.

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**Coral reefs** are over **50%** of the natural resources.

**Ecological Monitoring** is **effective**.

**Socio-economic Monitoring** is **planned**.

**ICRAN**

### **NOSY ATAFANA MARINE PARK, MADAGASCAR – DEMONSTRATION SITE**

The Nosy Atafana Marine Park is in the province of Toamasina in northeast Madagascar. Marine turtles and dugongs frequent the park and migrating humpback whales pass just outside the park's borders. Overexploitation and coral bleaching are the primary threats to marine resources. The Marine Park is a component of the UNESCO Biosphere Reserve of Mananara-Nord and is jointly managed by local communities and ANGAP (National Association for Protected Areas management). The Mananara Biosphere Project aims to develop integrated management based on communication, co-operation, education and training. Objectives of the park management focus on:

- Maintaining the quality and quantity of biodiversity;
- Conservation and rational management of marine resources; and
- Protection of the ecosystem of Nosy Atafana.

The overall management goal for the biosphere reserve is to develop the region and improve the quality of life of the coastal communities whilst achieving its objectives. The park is managed by local communities through a local contract with the managers, with the biosphere reserve being divided into 6 geographical regions for logistical purposes. Each regional sub-committee meets 2-3 times a year to evaluate the programs, activities and management of the reserve. Every sector of the coastal community is represented. Managers of the Marine Park are currently focusing their attention on raising support and awareness in local communities and building the capacity of enforcement officers.

There are many successful examples of the Mananara Biosphere Project in terms of meeting the goals of the Nosy Atafana Marine Park by using the participatory management approach. These will be used in capacity building for other regions of Madagascar.

**Ecological Monitoring:** Ecological inventories and the 2002-2006 management plan include extensive qualitative descriptions and species lists for the coastal marine ecosystems of the national park, and proposed zoning for the marine reserve. Ecological monitoring and a comprehensive inventory of biodiversity, including stock assessments and studies of exploited resources were planned within the context of ICRAN. However, this work has been hindered by the internal conflicts in Madagascar, despite the initial enthusiasm and political goodwill.

**Socio-economic Monitoring:** To date there has been no socioeconomic monitoring, but it has been identified as an important component in the park action plan that is being developed.

**Contact:** [www.icran.org/SITES/nosy.html](http://www.icran.org/SITES/nosy.html)

**Coral reefs are 40% of the natural resources.**

**Ecological Monitoring is planned.**

**Socio-economic Monitoring is planned.**



**ICRAN**

### **COUSIN ISLAND MARINE PROTECTED AREA, SEYCHELLES – ICRAN SITE**

Cousin Island is a small marine reserve southwest of one of the main islands in the Seychelles, Praslin Island. More than 217 species of fish inhabit the reefs and it is one of the most important turtle breeding sites in the Western Indian Ocean, with 30 to 100 hawksbill turtles nesting there annually. Seven species of breeding seabirds also nest there in numbers exceeding 300,000 individuals. The coastal environment is threatened by reclamation, port activities, pollution, sewage discharge, garbage, and marine debris.

The island was purchased by Birdlife International and designated a Special Reserve in 1975 under Seychelles national law. The initial purpose was to protect endemic birds, but current management also focuses on the marine environment. An awareness orientated, non-interventionist approach has been taken to:

- Protect and maintain the integrity of the island’s coastal and littoral habitats, especially the coral reef, its associated flora and fauna, and the internationally important breeding population of hawksbill turtles;
- Understand and mitigate negative long-term and external influences; and
- Raise and maintain public environmental awareness.

In 2004, Cousin Island won the Conde Nast Traveller’s Ecotourism Award for destination, which gives international recognition to those who are “committed to preserving the local environment, assisting and employing local people who live there and educating the guests who visit”. Cousin Island also received the 2003 British Airways Tourism Award for successfully combining conservation with tourism.

**Ecological Monitoring:** Attempts have been made to establish regular reef monitoring sites on the reefs and there are more than 120 scientific papers, articles and reports on Cousin’s biodiversity. Groupers, emperors, and snappers are more abundant and diverse within the reserve than at fished sites. A project to investigate the effects of coral bleaching on fish was undertaken in 2003 by the University of Stockholm. Two monitoring sites have been established under the national Coral Reef Network and mooring buoys for all boats have been in place since 2003.

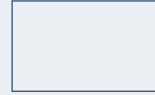
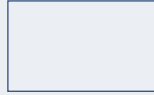
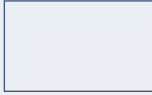
**Socio-economic Monitoring:** Tourist visitation (around 10,000 per year) to the island is regulated and managed by island based staff. The economic benefits to the surrounding communities and the private sector are based on educational tourism and it is estimated that these activities generate US\$600,000 in direct and indirect revenues.

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**Coral reefs** are 30% of the natural resources.

**Ecological Monitoring** is occasional.

**Socio-economic Monitoring** is occasional.



**ALDABRA ATOLL, SEYCHELLES – WORLD HERITAGE SITE**

Aldabra, one of the world’s largest atolls, is in the Southwest Seychelles, 420 km northwest of Madagascar. The area covers 35,000 hectares and it comprises a large shallow lagoon surrounded by islands and coral reefs. Aldabra has unique flora and fauna and is a refuge for more than 200,000 giant tortoises and large colonies of seabirds, including the only flightless bird in the Indian Ocean, the white-throated rail. It is also an important nesting site for green and hawksbill turtles. Because of the relatively limited exploitation and disturbance, marine fish are abundant and more than 90 species of corals have been identified.

Aldabra Atoll was to be developed as a military base in the 1960s, until concerned scientists and the Royal Society campaigned for its preservation. Research was initiated by the Royal Society in 1967 and a fully equipped research station was established in 1971. The area was designated a strict nature reserve in 1976 (Protection and the British Preservation of Wild Life Ordinance, 1970) and a special reserve in 1981 (Seychelles National Parks and Nature Conservancy Act).

Aldabra Atoll is maintained by the Seychelles Islands Foundation with external funding from the World Bank and the Global Environment Facility. WWF began monitoring tortoise and turtle populations in 1982, and scientists from the Smithsonian Institution and Cambridge University regularly work there. The Seychelles Islands Foundation produced a management plan in 1997, which has been accepted by the Seychelles Government. The present management strategy is to minimize human interference and to continue scientific research and monitoring. Maintenance of conservation interests and scientific value are dependant upon the Foundation to support both the research station and adequate staff levels. Because the Foundation is entirely dependant on subscription and donation income, a shortage of funds is a potential danger. Development is restricted to very small-scale tourism and fishing, with limited exploitation of natural resources.

**Ecological Monitoring:** The Aldabra Marine Program has 11 permanent monitoring sites (coral and reef fish) both in the lagoon and outside the atoll to track reef community structure and recovery. Monitoring in the Aldabra marine environment has become more frequent and research station staff has received training in resource management. The CORDIO program conducts occasional monitoring around Aldabra and adjacent atolls.

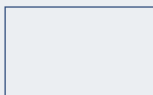
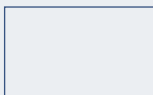
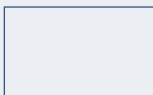
**Socio-economic Monitoring:** There are few people on the atoll and no need for monitoring.

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**Coral reefs** are 60% of the natural resources.

**Ecological Monitoring** is effective.

**Socio-economic Monitoring** is not planned.



**MANANARA-NORD MARINE RESERVE, MADAGASCAR  
– MAN AND THE BIOSPHERE RESERVE**

The Mananara-Nord Biosphere Reserve is located on the northeast coast of Madagascar and covers an area of 140,000 hectares. Madagascar has an extremely rich biodiversity with more than 85 percent of its species being endemic, making the conservation of its natural environment an international priority. The ecosystems in the biosphere reserve include tropical humid forest, sandy coastal plains with littoral vegetation, river vegetation, mangrove formations, marshlands, and coral reefs. Mananara Nord has gained international recognition as a pilot project that merges nature conservation, buffer zone development and participation of local communities in management activities. Approximately 47,000 people live in the area. Participatory research has been carried out to identify the needs of local communities (increased rice production and yields, diversification into small-scale stock rearing, improved health care aimed at decreasing mortality from malaria, diseases and financial support for education). The project operations have targeted native villages of ‘tavystes’ (highland rice cultivators) and fishermen around the national parks, with operations in sectors such as agriculture, rural infrastructure, health, education, fishing, animal husbandry, women’s organizations, research, conservation and adventure tourism.

A special effort has been made to reduce forest clearance linked to the shifting cultivation method of growing rice. With the co-operation of local farmers, a series of small dams and waterworks were constructed to irrigate intensively managed rice fields. Since rice yields doubled, this system directly benefited 465 families and contributed to forest conservation. The University of Tananarive provides the main scientific backing for the work at Mananara-Nord.

**Ecological Monitoring:** Monitoring and research occurs in many areas including biological inventories, marine biodiversity, multiple resource use and land use planning, and mapping of the different biosphere reserve zones.

**Socio-economic Monitoring:** The population has adopted environment-friendly techniques introduced by the UNDP conservation and sustainable development project. Examples include a diversification of rice cultivation and fishing methods. The introduction of co-management of the marine park has influenced the way the population responds to the notion of conservation.

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**Coral reefs are 20% of the natural resources.**

**Ecological Monitoring is effective.**

**Socio-economic Monitoring is effective.**



## SAHAMALAZA-ILES RADAMA, MADAGASCAR – MAN AND THE BIOSPHERE RESERVE

This Biosphere reserve in Madagascar was designated in 2001 and has followed Mananara-Nord in aiming to alleviate poverty while conserving the country's unique flora and fauna. It contains 12,402 ha of core area (4,183 ha of which is marine) and 40,900 ha of buffer zone (28,000 ha of which is marine). Located on the north-west coast of Madagascar, this biosphere reserve contributes to the conservation of 3 specific habitats: dry semi-deciduous forest, mangrove forest and coral reefs. About 42% of the species are endemic inside the reserve and the mangrove forests are made up of 8 different species.

Local people use the area for fishing crab and shrimp. Conservation of coral reefs is necessary for the sustainable development of the area and its population. The region is underdeveloped and poor, which increases the tendency of local people to over-utilise natural resources. In 2001, about 7,000 people lived in the biosphere reserve. Local development is hampered by many factors including: malnutrition, sanitary problems, illiteracy, immigration, low incomes, and over-exploitation of marine resources. The biosphere reserve provides a unique opportunity to promote sustainable management of woody vegetation and marine resources, to improve the agricultural production with priority to self-sufficiency, and to reinforce organisational arrangements, thus favouring local development and enhanced standards of living.

**Ecological Monitoring:** Regional shrimp fishing is monitored and a study is exploring alternatives for sustainable management of the natural resources.

**Socio-economic Monitoring:** No information was provided.

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**Coral reefs** are an **unknown** percentage of the natural resources.

**Ecological Monitoring** is **occasional**.

**Socio-economic Monitoring** is **unknown**.



## 8. STATUS OF CORAL REEFS IN SOUTH ASIA: BANGLADESH, CHAGOS, INDIA, MALDIVES AND SRI LANKA

ARJAN RAJASURIYA, HUSSEIN ZAHIR, K VENKATARAMAN,  
ZAHIRUL ISLAM AND JERKER TAMELANDER

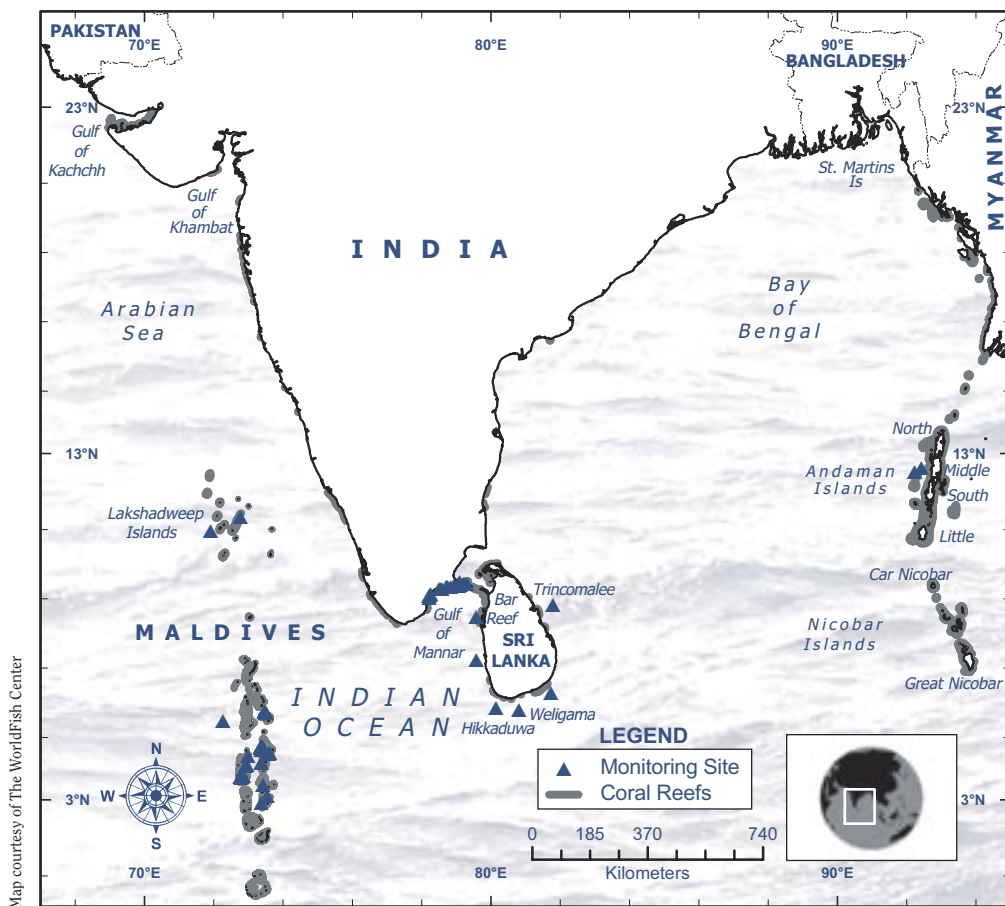
CONTRIBUTIONS FROM: M. A. HAQUE, J. R. B. ALFRED,  
S. M. MUNJURUL HANNAN KHAN AND M. SAZEDUL ISLAM

### ABSTRACT

The major coral reefs in South Asia occur in the Maldives, Chagos, Lakshadweep and the Andaman and Nicobar Islands. There are also extensive reefs in the Gulf of Mannar, and fringing and patch reefs elsewhere in India and Sri Lanka. Limited coral communities occur around St. Martin's Island in Bangladesh and on the Balochistan coast of Pakistan. Coral reef recovery following the 1998 bleaching was variable. Some areas show relatively good recovery, such as the severely bleached Lakshadweep Islands, where coral cover has doubled from less than 10% after the bleaching to 20% on some atolls, whereas in other areas there are indications of a phase shift, with algal growth smothering corals. Minor coral bleaching was observed in 2003 and 2004 in the Maldives, Sri Lanka, on the Indian side of the Gulf of Mannar and on St. Martin's Island in Bangladesh, with almost 100% recovery within months. Several reef areas have been declared marine protected areas (MPAs) in India, the Maldives and Sri Lanka. However, with the exception of Chagos, reef management remains poor in the region, particularly in India and Sri Lanka, where the exploitation of reef resources is increasing.

**100 Years ago:** Most reefs in the region were in pristine condition although the reefs near human populations may have been showing the effects of some resource exploitation. For example, chanks and sea cucumber were heavily exploited in the Gulf of Mannar region in the 1920s.

**In 1994:** Effects of over-fishing and destructive methods to collect reef resources, e.g. bomb fishing and mining, were clearly evident on reefs close to larger human settlements, resulting in reduced coral cover and ecosystem productivity. New or rapidly growing markets, including tourism and marine aquarium fish collection were affecting the reef resources, e.g. reef fish and lobster populations were depleted. Reefs in the Maldives and Sri Lanka were mostly recovering well from earlier plagues of crown-of-thorns starfish (COTS). There were no obvious signs of large-scale perturbations.



**In 2004:** Half of the reefs of the region are struggling to recover from the mass bleaching mortality in 1998, partly due to high levels of other stresses. There are indications of phase shifts to algal dominated reefs in many areas, whereas some areas are recovering rapidly. While reefs not affected by the bleaching mortality remain in relatively better health, they are often under threat from human activities. There are clear signs of over harvesting of fish and other reef resources such as sea cucumbers, chanks and spiny lobsters. Minor to serious bleaching was observed in Chagos, Sri Lanka, the Maldives and India in April – May 2004, but most of the affected corals have recovered relatively rapidly with low levels of mortality.

**Predictions for 2014:** The highly stressed coral reefs will not be managed better and even the more sustainable resource use practices will continue to deplete coral reef resources, with some damaged beyond recovery. This is the probable fate of about a third of the reefs of the region; another third will change from low-moderate threat status to high threat status. Areas under appropriate and effective management or remote from direct human pressures will continue to remain healthy, although all reefs in the region will continue to be vulnerable to large-scale bleaching events.



## INTRODUCTION

With the exception of the Andaman and Nicobar Islands and some parts of the Gulf of Mannar, coral reefs in the South Asian region were heavily damaged by the coral bleaching in 1998, with mortality ranging between 50% and 95% of the existing coral cover. Recovery of these reefs remains variable, partly due to high stress from human activities, although some areas are showing signs of a return to pre-bleaching levels of coral cover.

Virtually all coral reefs in the region outside MPAs are subject to various levels of exploitation. The pressure is exceptionally high in Sri Lanka and the Gulf of Mannar and Gulf of Kachchh areas in India, where poverty, population growth, coastal development and other land-based activities pose a serious threat to the existence of the reefs. Furthermore, management of coral reef areas remains poor in many parts of the region, both inside and outside MPAs, due to a lack of technical, institutional and financial capacity.

Regular ecological monitoring of coral reefs continues in India, the Maldives and Sri Lanka, based on training and financial support from national governments, the GCRMN South Asia Node, the Coral Reef Degradation in the Indian Ocean (CORDIO) program and other research projects funded by the Swedish aid agency Sida and other bilateral donors such as the Global Environment Facility (GEF). Increased emphasis has been put on pro-poor approaches to management, with training in socio-economic monitoring, implementation of socio-economic assessments, and development of alternative livelihoods in the region through initiatives such as CORDIO and GCRMN. These regionally oriented approaches remain a priority in South Asia.

This report provides an update to the 'Status of Coral Reefs in South Asia: Bangladesh, India, Maldives Sri Lanka' in the 'Status of Coral Reefs of the World: 2002'.

### Bangladesh

The only coral communities in Bangladesh are found around St. Martin's Island. A fringe of rocky substrate and coral communities extends about 200 m from the island, with a total reef area of less than 50 km<sup>2</sup>. The area is influenced by freshwater influx, monsoons and frequent disturbances such as cyclones and storm surges, resulting in high sedimentation as well as mechanical damage. Pressure from human activities, mainly resource exploitation, tourism and coastal development, is high. A shallow reef area about 15 km west of St. Martin's Island, locally known as Marphati bandth is not currently under any form of management, but is less damaged due to its inaccessibility to coral poachers.

### Chagos Archipelago

The British Indian Ocean Territory of Chagos is on the southern end of the Laccadive-Chagos ridge. The archipelago consists of 6 large atolls and many small islands and submerged shoals, with a total reef area of 3,770 km<sup>2</sup>. The largest atoll, Diego Garcia, hosts a US naval base. The coral reefs of Chagos are the best conserved in the South Asian region. There is comparatively little human activity, with the only human pressures arising from the military base, recreational yachts and some poaching.

### India

The total coral reef area in India is 5,790 km<sup>2</sup>, distributed between 4 major regions: Lakshadweep; Gulf of Mannar; Gulf of Kachchh; and Andaman and Nicobar Islands. Reef structure and species diversity vary considerably between the areas due to differences in size and environmental conditions.

Lakshadweep is an archipelago of 12 atolls surrounded by deep water, on the northern end of the Laccadive-Chagos ridge. In the Gulf of Kachchh, there are shallow patchy reefs growing on sandstone platforms that surround 34 islands. The reefs experience high salinity, frequent emersion, high temperature fluctuations and heavy sedimentation. In the Gulf of Mannar, coral reefs are found mainly around 21 islands between Rameshwaram and Tuticorin. Two former islands are now submerged, probably due to coral mining and erosion. The Andaman and Nicobar Islands consist of 530 islands with extensive fringing reefs which are mostly in good condition. Corals have also been reported from Gaveshani Bank about 100 km offshore from Mangalore, and several areas along the eastern and western coast of mainland India, e.g. the Malvan Coral Reef Sanctuary near Mumbai.

Large areas of coral reefs of India, with the exception of the Andaman and Nicobar Islands, were severely affected by the 1998 coral bleaching event. Reef resources are heavily exploited, particularly in the Gulf of Mannar and Gulf of Kachchh and to a lesser degree in the Lakshadweep and Andaman and Nicobar Islands.

### **Maldives**

The Maldives are in the centre of the Laccadive-Chagos ridge, and consist of 23 atolls, including 1,190 coral islands and numerous sand cays, within an area of 8,920 km<sup>2</sup>. The archipelago is surrounded by deep oceanic water and reefs are generally less threatened by human activities than in other parts of South Asia, as the human population is low and there are large distances between atolls. Coral reefs form the resource base for the two major economic sectors, tourism and fisheries, including the provision of bait for the offshore pole and line fishery for tuna. The tourism industry has become the largest income earner and the Government expanded the island hotel industry to all atoll groups of the Maldives in 2004, as a diversification strategy. Thus the tourism sector provides most of the reef management by reducing exploitation of fish, coral rock and sand and other reef resources in proximity to the resorts. Government interventions are steadily being reduced.

### **Pakistan**

Little is known about the coral communities of Pakistan. The total reef area is less than 50 km<sup>2</sup>. There are isolated coral patches on hard substrates along the Balochistan coast, but coral reef development is poor due to high sedimentation and turbidity. Coral development similar to that of the southern Arabian reefs may occur along the coast further west. No information on status and trends is available as few surveys have been conducted.

### **Sri Lanka**

There are fringing, patch and platform reefs around Sri Lanka including sandstone/limestone and rocky reef habitats, covering 680 km<sup>2</sup>. The most extensive coral reefs are offshore in the Gulf of Mannar region. The northeast and southwest monsoons govern environmental conditions for reef development. The southwestern coast of Sri Lanka has many rocky headlands and most fringing coral reefs have developed on the leeward side of these headlands due to strong waves generated by the southwest monsoon; there are no barriers to the south of Sri Lanka to reduce the impact of oceanic waves on the coast. There is better fringing coral reef development along the eastern coast, both on the leeward side of headlands and on offshore rocks and islands. Reefs are heavily exploited for resources and management intervention is generally inadequate.

## CORAL REEF STATUS AND BIODIVERSITY

### Bangladesh

The rocky substrate reefs have a coral cover of 7%, with 66 species of hard corals, dominated by branching (Acroporidae) and massive (Faviidae and Poritidae) species. There are 86 species of reef fish with damselfish, surgeonfish and parrotfish being the most common. The most abundant molluscs e.g. *Monodonta*, *Thais*, *Cypraea*, *Conus* and *Trochus* species are heavily traded.

### Chagos

The marine fauna of the Chagos Archipelago has more similarity with Indonesian and East African reefs than with the coral reefs to its north. Chagos has high diversity, with the 220 species of hard corals being among the highest recorded in the Indian Ocean. Fish abundance is expected to be higher than in the Maldives, but there have been no detailed surveys.

Coral reefs were severely depleted during the 1998 coral bleaching event, which destroyed up to 80% of live coral cover to a depth of 40 m. In early 2004, the coral reefs that were recovering from 1998, suffered very extensive repeat bleaching. However, the peak water temperatures were reduced by cyclonic winds bringing heavy cloud cover and rain for a critical 10 days when bleaching was clearly evident. Recent information suggests that the bleached corals in the lagoons of Diego Garcia mostly recovered, with little mortality.

### India

A total of 262 species of hard corals, 145 species of soft corals and 1,087 species of reef fish have been recorded from Indian coral reefs, but diversity varies significantly between areas. There are 104 hard coral species in the Gulf of Mannar, with dominant families being the Acroporidae, Faviidae and Poritidae, and more than 538 fish species. The 1998 coral bleaching event did not cause major losses in the Tuticorin group, and current live coral cover is 26%, dominated by massive coral species.

In the Andaman and Nicobar Islands, there are 203 hard coral species with *Porites* spp. being dominant in the northern and southern Andaman Islands, while *Acropora* spp. dominate the middle Andaman and the Nicobar Islands. The 1998 bleaching had far less effect on corals in the archipelago compared to other parts of the region. Currently live coral cover averages 65% and about 1,200 fish species have been recorded. The diversity of the Andaman and Nicobar Islands has greater affinity to Southeast Asia than to other reef areas in the South Asian Region due to the currents in the north-eastern Indian Ocean promoting larval exchanges with Southeast Asia.

The Lakshadweep Archipelago experienced severe coral mortality in 1998, and the live coral cover in the reef lagoons was reduced to less than 10%, with some variation between areas. Today the live coral cover is about 20%, with the previously severely damaged Kadmat and Agatti atolls showing good recovery.

The fringing coral reefs in the Gulf of Kachchh generally have low diversity, with around 42 hard coral species and 10 soft coral species. Live coral cover is generally low, currently about 20%.

### Maldives

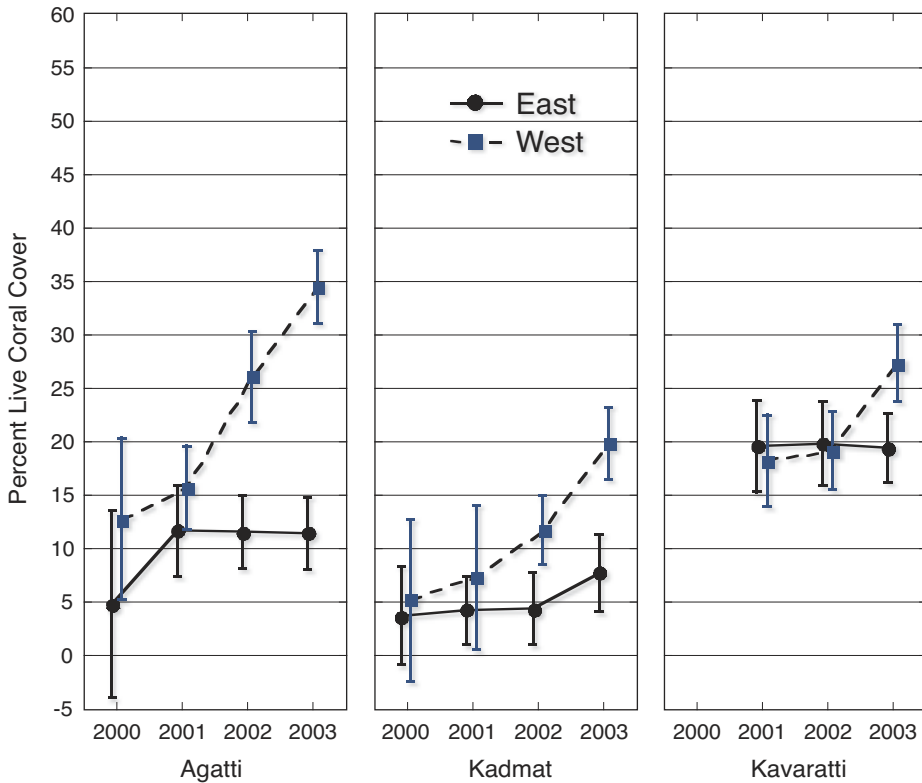
The coral reefs of the Maldives support a high diversity of reef animals, with about 250 species of corals and 1,200 reef and reef associated fish species. The bleaching in 1998 was most severe

in the northern and central parts of the archipelago, and recovery has been variable on reef flats and slopes. Reefs in the southern atolls, which were generally less affected by the 1998 bleaching, appear to be recovering faster and are currently in much better condition. However, in May 2004 a severe storm inflicted damage on Hithadhoo, resulting in a significant reduction in live coral cover on both the reef flat and slopes, particularly in shallow areas. Minor coral bleaching was observed in Ari, Vaavu and Addu atolls during April and May 2003. Monitoring of permanent sites established in 1998 continued in 2003-04, however, monitoring of some sites and fish surveys planned for 2003 were not completed due to a lack of resources. These surveys remain a high priority, including studying the effects of coral bleaching on reef fish populations.

### DIFFERENCES IN CORAL RECOVERY IN THE LAKSHADWEEP ISLANDS, INDIA

The 1998 El Niño climate change event caused considerable coral bleaching and mortality on the reefs of the Lakshadweep Islands. The benthic communities on many of these reefs were radically altered, with the potential for wide-ranging consequences for reef diversity and for the populations of reef-dependent organisms. Monitoring on the eastern and western sides of 3 atolls, Agatti, Kavaratti, and Kadmat showed a marked difference in the recovery of coral cover. Corals on the western sides of reefs showed very encouraging recovery between 2000 and 2003, dominated by rapidly growing branching and table *Acropora* species. In contrast, coral recovery on the eastern sides was either slow or virtually absent, although initially the recovery was good. These differences in coral cover were also observed in larger-scale, rapid assessments of more reefs in 2002.

The differences in coral recovery were not due to different recruitment patterns of the coral larvae, but to higher mortality of juveniles settling on the eastern sides. In 1998, the bleaching mortality was followed immediately by the summer monsoons that brought stormy conditions to the western sides in the Lakshadweep Islands. Much of the unstable dead coral on the west was cleared away relatively quickly from the reef, whereas even 4 years after the mortality event, there was much more dead standing coral on most eastern side reefs. Juvenile corals settled on these dead coral skeletons, which soon crumbled or toppled over resulting in considerable mortality of the new corals. Another major threat to new corals on disturbed reefs is overgrowth by fleshy macro-algae. However, on these reefs, the macro-algal cover remained very low between 2000 and 2003; probably because the strong ocean swells prevented accumulation of high nutrient levels and the large populations of herbivorous reef fishes, particularly scarids and acanthurids, kept the algae in check. Moreover the herbivores were the dominant trophic group on the reef after the bleaching, constituting 70% of the total fish abundance at some sites in 2000. Generally the fish communities in the Lakshadweep were remarkably stable after the bleaching, with a gradual increase in coral eating fishes as coral cover increased. These healthy fish populations were probably a major contributing factor to the rapid recovery of the Lakshadweep reefs after the massive coral mortality. From: Rohan Arthur, Nature Conservation Foundation, Mysore, India; rohan.arthur@jcu.edu.au.



*There was more rapid recovery in live coral cover on the western sides of coral reef atolls of Agatti, Kadmat and Kavaratti in the Lakshadweep Islands than on the eastern sides from 2000 to 2003 (error bars represent 95% confidence intervals).*

### Sri Lanka

About 190 species of hard coral have been recorded from Sri Lanka. The 1998 bleaching event had a profound effect on the western and southern coral reefs, while the damage was lower on the eastern coast. Monitoring data from shallow reefs in the table below show the initial losses from the bleaching and subsequent recovery at 4 sites in the northwest (Bar Reef Marine Sanctuary), southwest (Hikkaduwa National Park), south (Weligama) and east (Pigeon Island National Park).

*Live coral cover at 15 monitoring sites in the Maldives following the 1998 bleaching event shows generally consistent recovery, especially in the southern reefs of Villingili, Hithadhoo and Gan, which were less seriously affected in 1998 (n/m – not monitored).*

<b>Reef Sites</b>	<b>1998</b>	<b>1999</b>	<b>2000</b>	<b>2002</b>	<b>2003</b>	<b>2004</b>
<b>Reef flat (1-2 m)</b>	% cover	% cover	% cover	% cover	% over	% cover
Hondaafushi	1.6	0.5	0.9	1.7	3.1	n/m
Finey	0.7	0.1	0.3	1.4	2.5	n/m
Hirimaradhoo	0.7	0.3	0.4	1.1	1.1	n/m
Feydhoofinolhu	1.7	2.3	1.8	1.9	n/m	n/m
Bandos	1.9	7.6	5.0	6.9	n/m	n/m
Udhafushi	1.3	1.5	2.1	2.9	n/m	n/m
Fesdhoo	3.3	3.8	9.9	22.1	n/m	27.2
Maayaafushi	0.6	0.9	1.5	2.7	n/m	4.8
Velidhoo	0.2	0.2	0.7	2.3	n/m	2.3
Ambaraa	1.2	0.9	3.2	2.9	4.8	n/m
Wattaru	2.8	2.4	2.7	3.7	5.0	n/m
Foththeyo	5.0	2.7	4.1	5.0	9.7	n/m
Gan	4.0	4.5	5.0	12.9	n/m	17.0
Villingili	4.3	n/m	9.2	13.2	n/m	n/m
Kooddoo	1.0	2.3	n/m	6.0	n/m	n/m
<b>Reef flat (3 m)</b>						
Hithadhoo				51.6	59.1	32.0
<b>Reef slope (7 m)</b>						
Gan				42.8	n/m	n/m
<b>Reef slope (10 m)</b>						
Villingili				54.3	n/m	61.4
Hithadhoo				40.9	62.6	51.7

*There is evidence of recovery of corals on Sri Lankan reefs after 1998 when coral bleaching dramatically reduced coral cover to almost zero on many reefs on the western coast, whereas reefs on the eastern coast (e.g. Pigeon Is.) were not affected; n/m – not monitored*

<b>Reef sites</b>	<b>Depth</b>	<b>Pre-bleaching</b>	<b>1999- 2000</b>	<b>2001-2002</b>	<b>2003-2004</b>
Bar Reef Marine Sanctuary	0 - 3 m	78.5%	Near 100% mortality	Some new colonies	17.7%
Hikkaduwa National Park	0 - 3 m	47.2%	7.0%	12.0%	10.1%
Weligama Reef	0 - 3 m	92%	28.0%	54.0%	70.6%
Pigeon Island National Park	0 – 3 m	n/m	51.3%	n/m	54.4%

Recovery of bleached reefs was slower on the northwestern, southwestern and eastern coasts (Bar Reef, Hikkaduwa and Weligama and Trincomalee respectively). Some areas that showed recovery in 2002, have again been overgrown with calcareous algae (*Halimeda* sp). Only the fringing reef at Weligama in the south has shown good recovery, primarily due to an increase in branching *Acropora* spp. Recovery on large coral banks in the Bar Reef Marine Sanctuary is patchy, with strong growth predominantly due to the branching *Pocillopora damicornis* and plate forming *Acropora cytherea* in some areas. The rest of the fringing coral reefs in the southwest and south have not been recolonised by *Acropora* or by *Pocillopora*, although these were common before 1998. The reefs have thus become covered by low-profile foliose *Montipora*. Minor coral bleaching was observed in April and May 2004 just prior to the onset of the southwest monsoon, but no mortality was recorded.

## THREATS TO CORAL REEFS AND MANAGEMENT ISSUES

The threats to the coral reefs vary among the countries and reef areas in South Asia. In Bangladesh, mainland India and Sri Lanka there is continual damage to coral reefs from human activities such as the use of destructive fishing methods, over harvesting of resources, development and pollution, while in the Andaman and Nicobar Islands, Lakshadweep, and the Maldives these threats are much lower. There is little direct damage to reefs in Chagos due to low human populations and better protection. However, climate change poses a serious threat to all reefs in the region.

### Bangladesh

There is a large market for corals and associated fauna, including e.g. gastropod and bivalve shells and marine turtles, operates in the Cox's Bazaar district. Merchandise is indiscriminately harvested from around St Martin's Island, and other coastal areas of Bangladesh, although it is suspected at least some of the coral skeletons on sale may come from the Mergui area in Myanmar. The Government of Bangladesh declared St. Martin's Island a protected area in 1999, but little action has been taken to manage the area. Land ownership is largely private, and indiscriminate coastal construction and increased tourism pressure pose a potential threat to the reefs. Construction of a large tourist hotel in 1999 led to increased sewage runoff. Construction of jetties and passenger ship operation facilities commenced in 2002.

### India

All coral reef areas continue to be under stress, especially in the Gulf of Mannar and Gulf of Kachchh, where coral mining and destructive fishing practices are most prevalent. Sedimentation and pollution pose major threats.

India developed a National Biodiversity Strategy Action Plan in 2004 which includes a conservation strategy for coral reefs. This complements the legislation banning the collection of corals and reef-associated fauna (sea cucumbers, molluscs, gorgonians, sponges, seahorses, pipefishes and sharks) under the Wildlife Act of 1972 and 2002. The plan also aims to regulate coastal resource access and benefit sharing.

The Gulf of Mannar Trust was formed in 2003 to undertake a UNDP GEF project on management of coral reefs in Gulf of Mannar, and an implementation office was opened at Ramanathapuram. A UNDP GEF project on land use patterns, biodiversity conservation and management in the Andaman Islands is in the final stages of preparation, awaiting endorsement by local authorities and approval by GEF. In May 2004, the Ministry of Environment and Forests sanctioned grant funds to organisations to undertake coral reef studies in the Andaman Islands



and Gulf of Kachchh. Projects on Integrated Coastal Zone Management with specific reference to development of tourism have been implemented in the Andaman Islands by the Institute of Ocean Management, Anna University, Chennai and in the Lakshadweep Islands by the Centre for Environmental Science Studies, Thiruvananthapuram. A series of projects including coral reef surveys and restoration, socio-economic assessments in reef dependent villages, and awareness raising efforts on the Tuticorin Coast, Gulf of Mannar are being implemented by the Suganthi Devadason Marine Research Institute (SDMRI), with support from the CORDIO Program. Additional options for income diversification for 60 families have been provided through this program that started in early 2002. The Centre of Action Research on Environment, Science and Society (CARESS) is establishing a community based coral reef socio-economic monitoring program in the Lakshadweep Islands in 2003. This project is also supported by CORDIO, and is a continuation and expansion of a GCRMN pilot project in 2001.

### **Maldives**

Several coral reef management activities are being undertaken in the Maldives, including a complete review of existing laws and regulations on fisheries and marine resource management that also encompasses coral reef resources. Faafu atoll has been identified as a High Priority Area for coastal resource management. The Faafu grouper management pilot project has been initiated with technical help from the Asian Development Bank as part of the Coastal and Marine Resources Management and Poverty Reduction in South Asia project. Addu atoll (locally known as Eidhegili Kulhi) and associated reefs were declared a model site for the Australian Aid Maldives Protected Area System Project in 2004. Implementation of the UNDP GEF supported Atoll Ecosystem Management project formulated for Baa Atoll commenced in 2004 and is progressing as planned.

### **Sri Lanka**

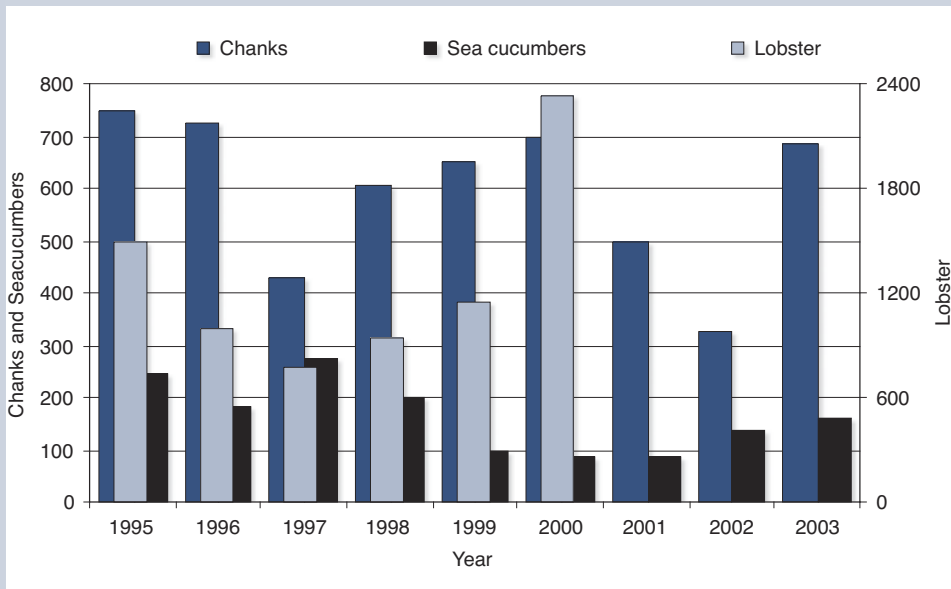
Blast fishing and purse seining continues, even in reef areas designated for protection such as the Pigeon Island National Park in Trincomalee, the Bar Reef Marine Sanctuary and Rumassala Sanctuary. The coast guard is confined to land-based activities and has not taken an active role in prevention of illegal fishing operations and coral mining. Coral mining is rampant in Rekawa, despite a USAID program from 1991-1996 which was established to provide alternative sources of livelihood to coral miners. Miners now use large rafts to drag coral blocks to shore. A socio-economic study of coral mining communities in the south-western coastal areas, identified a lack of alternative employment opportunities as the major reason for continued coral mining. In the same area in 2003 and 2004, the Turtle Conservation Project and CORDIO implemented a pilot demonstration project during which 20 coral mining women were provided opportunities to shift into alternative livelihoods. The Coastal Resources Management Project continues its special area management programs at the Bar Reef Marine Sanctuary, Unawatuna and several other coastal lagoons and estuaries along the western coast. Two new protected areas; the Pigeon Island National Park in the northeast and Rumassala Sanctuary were declared in 2003 to protect coral reefs, however there has been no management due to lack of human, institutional and financial resources.

## **TRAINING AND CAPACITY BUILDING**

In India, an Australia-funded training and capacity building program has trained 25 scientists in scuba diving, taxonomy and GCRMN monitoring methods. The training was carried out during pilot monitoring of coral reefs in the Andaman and Nicobar Islands and the Lakshadweep islands in 2003. In 2004, India held a stakeholder workshop at Port Blair, Andaman Islands, to

## UNCONTROLLED SCUBA COLLECTING IS DEPLETING KEY TARGET SPECIES IN SRI LANKA

Divers started using scuba gear to collect for the marine aquarium trade in Sri Lanka in the 1960s, and by the 1970s there were about 50 fishers using scuba for the aquarium trade or to collect spiny lobsters. Today there are about 500 fishers using scuba to harvest aquarium species, sea cucumbers, spiny lobsters and chanks (*Turbinella pyrum*, used for ornamental purposes such as making pearl-like buttons and incorporation into paints in Bangladesh and India). The annual export of sea cucumbers, chanks and other shells decreased between 1995 and 2001, probably because of resource depletion. Field



observations confirm that populations of sea cucumbers are severely depleted to about 30 m in many areas after scuba divers targeted them in the mid-1990s. They are now collected mostly at night as they feed. Scuba is used to collect in MPAs, e.g. to harvest chanks within a fisheries management area in the southeast. Increased export since 2001 is due to the opening of previously inaccessible areas in the north and east following the signing of a cease-fire agreement in 2001. Unlike chanks and sea cucumbers, which are harvested exclusively for export, a large portion of the spiny lobster harvest is eaten in tourist restaurants in Sri Lanka. An increased effort until 2001 resulted in the spiny lobsters being over-fished in the west and south, leading to decreasing sizes of lobsters caught and fewer lobsters seen on the reefs. This is the likely scenario for the northern areas soon. Recent data on lobster harvest are not available.

There are also serious health problems associated with using scuba. Exporters usually supply the equipment to the divers, but do not provide training, and many now suffer from the bends. For example, some divers on the eastern coast are working to a depth of 50 m, using

multiple scuba cylinders but without adequate decompression, resulting in some crippling cases of the bends. The naval base at Trincomalee has the only decompression chamber in the area, but it is too far from most dive sites. Thus divers attempt to manage the bends with in-water recompression, further adding to the dangers.

The Sri Lanka Fisheries and Aquatic Resources Act 1996 places restrictions on reef harvesting, but there are no regulations on the use of scuba. The Department of Fisheries and Aquatic Resources formed a committee in 2004 to develop special regulations and management recommendations to stop the over-exploitation of sea cucumber and chanks. However, much remains to be done as there is active scuba harvesting of sea cucumbers, chanks and lobsters, even within MPAs, e.g. in the Bar Reef Marine Sanctuary, which is nominally under special area management of the Coastal Resources Management Program. From Arjan Rajasuriya, National Aquatic Resources Research and Development Agency, Sri Lanka – arjan@nara.ac.lk

identify gaps in coral reef management. The CORDIO program has provided 3 PhD research scholarships in Tuticorin, Gulf of Mannar for coral reef research.

The National Aquatic Resources Research and Development Agency (NARA) and the Sri Lanka Sub-Aqua Club conducted monitoring using Reef Check in Trincomalee in 2003. A team of volunteer divers joined the activities in 2004 with financial support from the Hong Kong and Shanghai Bank. In addition, during 2003-2004, CORDIO and NARA provided training and financial support for the establishment of a coral reef unit at Eastern University, Batticaloa. They also finalised their first surveys of Passikudah Reefs on the East Coast of Sri Lanka.

## **AWARENESS RAISING**

The 'Handbook on Hard Corals of India' (2003), and the 'Bibliography and checklist of corals and coral associated organisms of India' (2004), were published by the Zoological Survey of India to encourage researchers to study the diversity of Indian coral reefs. Twenty-nine posters on marine animals and coral reef associated organisms were also published to create awareness among Indian school children. SDMRI has published a Field Guide on stony corals of Tuticorin, and implemented coral reef education programs for fisher women in the Gulf of Mannar.

In Sri Lanka, several workshops and awareness building programs have been conducted within the Coastal Resources Management Program to educate the public and school children on the value of coastal resources, including coral reefs. IUCN Sri Lanka has completed the CORDIO funded 'Sri Lanka Reef Watch Program Phase 2' with more than 1000 schools along the coast of Sri Lanka receiving educational packages about coral reef issues. Coral reefs are now included in the formal school curriculum of Sri Lanka.

In the Maldives, information dissemination by the popular media has been a high priority. Radio programs highlighting the importance of reefs have been produced, and billboard displays are evident in several island communities. The Ministry of Fisheries, Agriculture and Marine Resources of the Maldives is currently developing a training program in order to establish reef monitoring in island communities, based on Reef Check methods. The program is targeted at

school children with the aim of exposing them to basic monitoring techniques that can gather comparative and consistent data.

### RECENT CORAL BLEACHING IN SOUTH ASIA

Minor coral bleaching was observed in South Asia in March - April 2003 and 2004; the same months as massive bleaching occurred in 1998. This time coincides with the warm weather prior to the southwest monsoon. Coral bleaching was observed in India on some islands of the Gulf of Mannar, with 10 - 20% of massive corals bleached, but the majority recovered in the second half of the year. In the Maldives, there was significant coral bleaching in Faafu, Vaavu, Ari and Addu atolls, with an estimated 10-20% of coral colonies totally bleached and a similar percentage showing partial mortality. However, the majority of the corals recovered within months. In Sri Lanka, similar minor bleaching was observed in very shallow areas of Dutch Bay in Trincomalee and at Rummassala, where the water temperature rose to about 31°C. Corals recovered within about 3 weeks. At St. Martin's Island, Bangladesh, some *Goniapora* and *Platygyra colonies* bleached in the south western and north western shallow areas in 2003 and 2004. Some bleaching primarily of *Porites* colonies was also recorded in 1998 (from A. Rajasuriya, K. Venkataraman, H. Zahir, M. Z. Islam).

### STATUS AND MANAGEMENT OF MARINE PROTECTED AREAS

India has 36 MPAs, including 3 Man and Biosphere reserves. In the Maldives, 25 protected sites have been established centred on tourist dive locations, and a MPA system is being developed by the Government with support from AusAID. In Sri Lanka 2 MPAs (Rumassala Sanctuary and Pigeon Island National Park) have been declared, bringing the number to 4 MPAs in the country with coral reefs. Bangladesh has one MPA; St Martin's Island.

Management remains inadequate in most MPAs in South Asia, particularly in India, Sri Lanka and Bangladesh. While sufficient legislation, regulatory frameworks and management plans exist in most cases, they are frequently not up to date or fully appropriate. Enforcement and implementation are inadequate. Primary causes for this include a lack of technical and financial capacity, inefficient coordination between various government and non-government bodies, as well as corruption in some institutions. A lack of alternative livelihoods for coastal populations, that use resources in MPAs in breach of regulations, compounds the problems. In the Maldives, reef-based tourism potentially influences reef health in MPAs, although it also offers some protection against other extractive uses.

*The current status of marine protected areas in South Asia.*

<b>Marine protected areas</b>	<b>Status</b>	<b>Management</b>	<b>Major issues</b>
<p><b>Bangladesh</b> St Martin's Island is listed in the National Conservation Strategy</p>	Degraded	Little management due to lack of resources & development priorities	Rapid resource depletion, souvenir collection, sedimentation, pollution & physical damage.
<p><b>India</b> Gulf of Mannar Biosphere Reserve</p>	Damage continues especially in nearshore areas from human activities; bleaching recently observed.	Management is inadequate & habitats continue to degrade.	Coral mining, land-based pollution, unmanaged resource harvesting.
Gulf of Kachchh Marine National Park	Corals are recovering but condition of reefs is poor.	Management is inadequate & habitats continue to degrade	High sedimentation & pollution
Lakshadweep	Corals are recovering slowly.	Has improved	Coral mining & fishing pressure in some islands
Mahatma Gandhi Marine National Park, Andaman and Nicobar	Condition of corals & reef resources is good. Recent bleaching was observed.	Management has improved after 2002, but needs improving	Sedimentation, crown-of-thorns starfish, souvenir collecting, minor bleaching
Rani Jansi Marine National Park in Richie's Archipelago, South Andaman Islands	Condition of corals & reef resources good, with rich diversity of corals & other fauna, Corals recovering & resources	Management plans implemented, but human impacts are generally low.	Little is known, no coral mining, or fishing including destructive practices, little sedimentation & low tourism impacts.
<p><b>Maldives</b> 25 MPAs (Protected dive sites).</p>	declared protected. Some sites need review	Active management is inadequate. Sites are used by dive operators.	Dive tourism – impact of tourism on MPAs unknown.

### Sri Lanka

Bar Reef Marine Sanctuary	Coral are recovering well but fishing pressure increased	Coastal Resources Management project developing strategies & planning MPA management.	Extractive use has increased, including fishing & especially sea cucumber & chanks collection
Hikkaduwa National Park	Corals in poor condition due to sedimentation & high visitor pressure	No management	Sedimentation, Visitor pressure & physical damage by boats & trampling of corals
Rumassala Sanctuary	Corals in poor condition; recent bleaching observed	No management	Blast fishing, ornamental fish collecting & visitor pressure
Pigeon Island National Park	Corals in good condition	No management	Visitor pressure & destructive fishing in vicinity.

## CONCLUSIONS

### Coral Reef Status – Past, Present and Future

**100 Years ago:** Reefs in South Asia were mostly in ‘pristine’ condition. Some fisheries, e.g. chank and sea cucumber collection in the Gulf of Mannar in the 1920s, as well as coral mining had damaged the reefs closer to large human settlements. However, the lower human populations meant that over-extraction of reefs, and destructive fishing methods such as seine nets with rollers and bombs were not used. Consequently the reefs recovered relatively quickly from large-scale or localised damage caused by storms. Mass-disturbances such as the bleaching event in 1998 were not reported.

**In 1994:** Many reefs in remote areas that had low human populations were still relatively healthy. However, some areas, such as the Andaman Islands, showed some damage from increased sediment levels caused by logging and deforestation. The effects of mining, over-fishing and destructive fishing were apparent in many reef areas, especially in India and Sri Lanka, largely due to population growth in poor reef-dependent communities. The tourism boom, especially in the Maldives and Sri Lanka, was gaining momentum and posing threats to the reefs. In addition to tourism, new and growing markets such as the trade in aquarium species, sea cucumbers, and lobsters for tourist restaurants, reduced populations of these reef resources and altered fish communities. Reefs that were plagued by COTS in the early 1990s were recovering relatively well by 1994, but there was little effective management. In the Maldives, the initial coral reef management was being undertaken by tourist resorts to protect their reef resources. Sri Lanka had already developed an impressive set of legislation and established MPAs but the efforts were largely ineffective, because few attempts were made to control damaging activities. Large areas of northern Sri Lanka were inaccessible due to major ethnic disturbances. In India, there was minimal recognition of coral reefs by the Government, the major reef studies were taxonomic, and there were no MPAs or conservation measures in place.

**In 2004:** The effects of the mass bleaching in 1998 are still visible in virtually all parts of the region that were affected. The combination of high mortality and continued high stress, such as over-fishing, destructive fishing, mining and land-based activities, has further degraded reefs particularly in India and Sri Lanka, where there are large reef areas with dead coral colonies covered in algae. Many unconsolidated rubble beds remain in the Maldives and there are reports of reefs where the dominant organisms are soft coral-like animals (corallimorpharians). A third to half of coral reefs in the region are now effectively dead, and a further 30% are threatened. Some more remote reef areas are still in relatively good health, with some showing encouraging signs of recovery. There has been considerable growth in human populations, resulting in continuous increases in pressure on the reefs for provision of food and livelihoods. Many reef associated biota such as sea cucumbers and lobster, show clear signs of over-harvesting or population crashes. Minor bleaching was reported from Sri Lanka, the Maldives, Chagos, and India in 2004. However, most of the affected corals recovered relatively well within a short period. The region established a strong coral reef monitoring network in 1996 and all countries have active monitoring programs in most of their coral reef regions, although monitoring in the Maldives has been intermittent. India established the Indian Coral Reef Initiative and a parallel monitoring network, and is making major efforts to conserve and manage their coral reefs. They produced an outstanding handbook on the corals of India in 2004. Coral reef management in Sri Lanka continues to be inadequate and the reefs continue to degrade, even in declared MPAs where there is virtually no enforcement of regulations. In the Maldives, where the Government does not have sufficient financial, human and logistic resources for coral reef management and monitoring, the majority of these tasks are conducted by the tourism industry.

**Predictions for 2014:** Unless the current rates of over-exploitation and destructive harvesting are controlled, particularly in India and Sri Lanka, the coral reefs in the region will continue to deteriorate and many will degenerate completely. The major pressures on reefs are the rising levels of poverty among increasing coastal populations, and local economic conditions that often drive reef destruction. For example, as long as reef mining is more profitable in the short term than other reef uses by coastal people, and authorities fail to enforce regulations, reefs will continue to be mined. Pressure is also increasing from external market demand, which is driving the harvesting of ornamental fish, sea cucumbers and other resources. Without improved controls, it will be difficult to divert the livelihood strategies of communities away from dependence on reef exploitation.

Improved management could increase the resilience and resistance of the coral reefs by helping to facilitate recovery from the 1998 event, and improve the chances of withstanding another similar event; which appears inevitable based on current predictions. In the Maldives and Chagos, direct pressures on the reefs are lower than elsewhere in the region, but these archipelagos are probably more vulnerable to damage from climate change. Another severe heating event like 1998 would be even more damaging to the reefs and may result in localised extinctions of coral species, from recovering reefs. However, there are also early indications of increased resilience to bleaching in some areas and some species. Thus, the prediction for reefs in areas currently under high levels of stress is not good, while reefs in more remote areas have a better chance of recovering from the 1998 bleaching and withstanding other perturbations. However, there is a risk that over-harvesting of reef resources will shift to these remote areas, if the resource stocks collapse in heavily exploited areas. Greater focus on developing alternative livelihoods that are sustainable and realistic options for coastal people is essential.



*The national coral reef coordinators and local experts provided these estimates of coral reef status and predictions for the future. The estimates cover the amount of reef area that: is now effectively dead; was reduced to less than 5% coral cover in 1998; is recovering following damage in 1998; is under critical threat of destruction in 10 to 20 years (if urgent action is not taken); and threatened with destruction in 20 to 40 years. The last two are the high to very high risk and the medium risk categories of the Reefs at Risk process; reef area taken from the World Atlas of Coral Reefs (2001).*

South Asia	Coral Reef Area km <sup>2</sup>	% Reef Now Dead	% Reef Destroyed in 1998	% Reef Recovered After 1998	% Critical Stage Reefs	% Reefs Threatened Stage
Bangladesh	50	25	10	50	50	25
Chagos	3770	50	75	50	0	20
India	5790	25	30	15	20	25
Maldives	8920	55	80	25	5	25
Sri Lanka	680	35	40	15	10	45
<b>Region Total</b>	<b>19210</b>	<b>44</b>	<b>62</b>	<b>31</b>	<b>9</b>	<b>25</b>

## RECOMMENDATIONS

- Initiatives on conservation, development and poverty reduction in coastal areas need to be more effectively integrated, reflecting their inter-connectedness and ensuring problems that are linked are not addressed in isolation;
- Increased focus is needed on development of sustainable alternative livelihoods to reduce the pressure on reef resources. These must be viable options for coastal populations, and could include:
  - developing suitable approaches and tools for livelihood diversification that are poverty focused and integrated with wider coastal development and poverty reduction strategies;
  - building capacity in the region to address sustainable livelihoods development for reef users;
  - monitoring the effectiveness and sustainability of alternative livelihood initiatives, including development of methodology; and
  - identifying and undertaking research needed to support the above activities.
- Management of coral reef areas should be improved by:
  - Increasing the efficiency in use of funding;
  - increasing cooperation between agencies, including government institutions and ministries, with complementary or overlapping mandates;
  - developing partnerships with all major stakeholders and ensuring that governments and NGOs function cooperatively;
  - increasing technical capacity among key institutions;
  - increasing funding to key institutions, while ensuring that they operate transparently and efficiently;
  - increasing enforcement of existing laws such as those relating to coral mining in Sri Lanka, while ensuring that populations are not deprived of livelihood options;

- enforcing regulations developed for MPAs;
  - establishing a representative network of MPAs in the region, through an analysis of ecological coherence and connectivity in present MPAs, identification of gaps and declaration of new MPAs as needed (this includes all forms of protected areas, i.e. including fish refugia, fisheries management areas etc.).
- Research into current conservation status of food fishes, lobsters, chanks, sea cucumbers, ornamental fishes and other reef-associated biota is needed.
  - Appropriate regulation mechanisms should be developed to ensure that fisheries are sustainable, possibly through introduction of licences and certification schemes;
  - Increase ecological and socio-economic monitoring and research, to provide reliable data and information to meet national and regional requirements;
  - Develop mechanisms for managing coral reef information, including monitoring data, and ensure that these are available to coral reef managers and decision makers.

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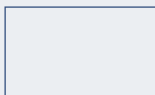
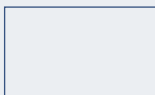
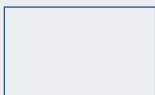
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### GULF OF MANNAR, INDIA - MAN AND THE BIOSPHERE RESERVE

The Gulf of Mannar Biosphere Reserve stretches for 180 km along the coast of India across from Sri Lanka and covers an area of 1,050,000 hectares. It is one of the world's richest regions from a marine biodiversity perspective and comprises 21 islands, including estuaries, algal communities, sea grasses, coral reefs, salt marshes and mangroves. Among the Gulf's 3,600 plant and animal species are the globally endangered sea cow (*Dugong dugon*) and 6 mangrove species endemic to peninsular India. Significant elements of the Gulf of Mannar include the largest remaining feeding grounds for the dugong and 5 species of marine turtles: Green, Loggerhead, Olive Ridley, Hawksbill and Leatherback. The Gulf's seagrass communities are valuable habitats for commercial species such as prawns, sea cucumbers, and several species of seaweeds. The Gulf of Mannar also has 17 species of coral from 7 genera.

The inhabitants are mainly Marakeyars, local people directly dependent on fishing, seaweed collecting, or other coastal activities for their livelihoods. There are about 47 villages along the coastal part of the biosphere reserve which support 100,000 people (200,000 seasonally as of 2001). The Global Environmental Facility (GEF) financed an initiative in the Gulf of Mannar Biosphere Reserve aimed at strengthening the capacity of local communities, particularly women, for managing the coastal ecosystem and wildlife resources. The project will demonstrate new approaches to the integration of conservation, sustainable coastal zone management and livelihood creation through an innovative institutional and financial mechanism.

**Ecological Monitoring:** Many Indian research and development institutions, including the Central Marine Fisheries Research Institute, National Institute of Oceanography, and Madras University, have on going research and monitoring programs in the Gulf. Research focuses on climate change, coral mining, pollution, bio-prospecting, and threatened species. Long-term monitoring of fisheries and of marine flora and fauna has helped to develop an integrated ecosystem management model for sustainable resource harvest.

**Socio-economic Monitoring:** No information was provided.

**Contact:** Ministry of Environment and Forests, Paryvaran Bhavan - C.C.O. CompJex Lodhi Road, New Delhi, India | 10 003 Email: pccfwl@vsnl.com)

**Coral reefs are 50% of the natural resources.**

**Ecological Monitoring is effective.**

**Socio-economic Monitoring is unknown.**



**RAMSAR**

### **DIEGO GARCIA, UNITED KINGDOM (BRITISH INDIAN OCEAN TERRITORY) - RAMSAR SITE**

Diego Garcia is a particularly good example of a relatively unpolluted coral reef system providing a valuable link to the marine ecology of the Indian Ocean. Covering a total area of 35,424 hectares, this wetlands site provides habitat for marine flora and fauna including endemic coral species and endangered sea turtles. It supports 220 coral species of 58 genera, and is otherwise rich in marine life. Within the seagrass beds a number of fish species have been recorded which have not been seen anywhere else in the Archipelago. The site is also important for breeding seabirds and serves as a valuable nursery ground for fish stocks.

Diego Garcia is the southernmost atoll of the Chagos Archipelago. It is a mid-ocean coral reef system and the only known area of seagrasses at Diego Garcia is found on the eastern side of the lagoon. The island consists of subtidal rock (including rocky reefs) and subtidal sediments (including sandbank/mudbank) and is owned by the Crown Estate. Part of Diego Garcia atoll is excluded from protection under a 1976 UK/US Agreement and is set aside for military uses as a US naval support facility. The site and adjoining areas are used for research, recreational fishing, and military activities.

A fully comprehensive Natural Resources Management Plan for Diego Garcia was issued in 1997 and is currently being revised. Nature and Strict Nature Reserves have also been established. The site's international importance is legally recognised in the BIOT Conservation Policy Statement (1997). The enforcement of conservation measures is the responsibility of the Commissioner's Representative, assisted by the BIOT police and fisheries officers.

**Ecological Monitoring:** No information was provided.

**Socio-economic Monitoring:** No information was provided.

**Contact:** Commissioner's Representative, NP 1002 BFPO 485, Diego Garcia, British Indian Ocean Territory.

**Coral Reefs** are an **unknown** percentage of the natural resources.  
**Ecological monitoring** is **unknown**.



## 9. STATUS OF CORAL REEFS, CORAL REEF MONITORING AND MANAGEMENT IN SOUTHEAST ASIA, 2004

KARENNE TUN, LOKE MING CHOU, ANNADEL CABANBAN, VO SI TUAN, PHILREEFS, THAMASAK YEEMIN, SUHARSONO, KIM SOUR AND DAVID LANE

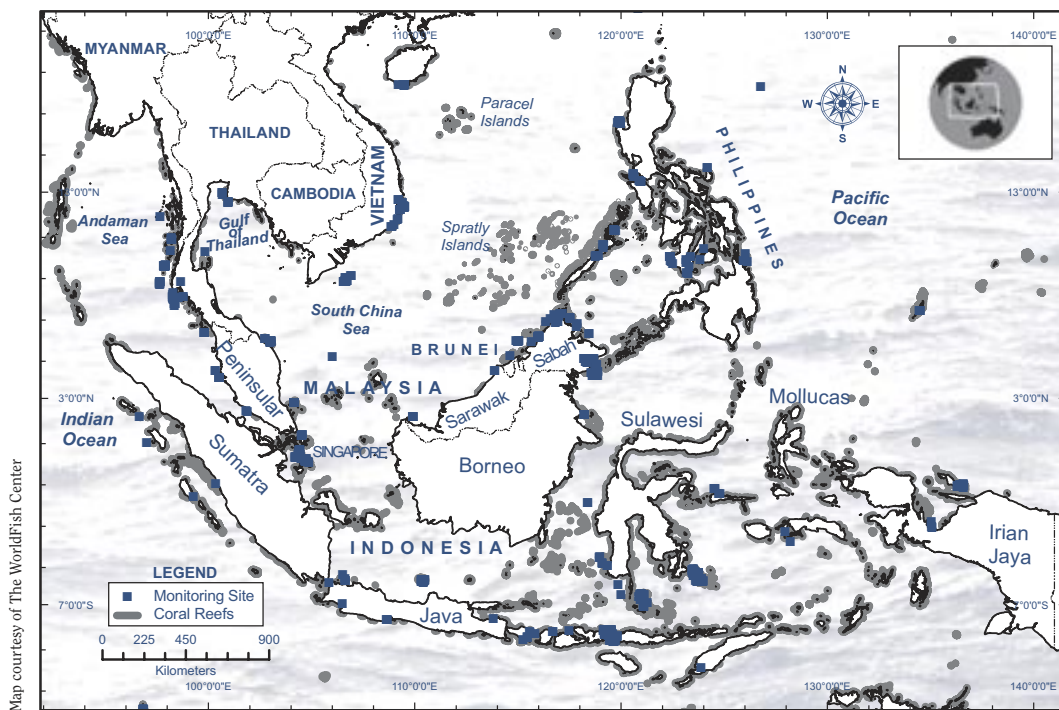
### ABSTRACT

This 2004 assessment of coral reefs in Southeast Asia (SEA) continues to show an overall decline in reef condition, but it does offer a glimmer of hope for the future. While the decline is regional, it is not reflected in the reef status in all countries. For example, Indonesia continues to show slight, but definite improvements in reef condition from 1999, while preliminary data from Myanmar show that the reefs surveyed are relatively healthy, with most of the reefs surveyed having more than 75% live coral cover. The continued decline in reef in the Philippines, Vietnam, Thailand and Singapore is still a major concern, and although threats to reefs remain high and dominated by anthropogenic factors, more active management initiatives are being implemented throughout the region, which provides a sense of optimism for the coral reefs of SEA.

Coral reef monitoring in SEA started more than 20 years ago, with the Philippines starting in the late 1970s. Monitoring in a core regional network of Indonesia, Malaysia, Philippines, Singapore and Thailand started in 1986 with funding from the ASEAN-Australia Living Coastal Resources (LCR) project, until 1994. Monitoring since has varied between countries; some have continued and expanded monitoring programs and strengthened in-country coordination and capacity building; others have reduced monitoring and fragmented or weakened coordination. However, SEA countries have begun to re-examine their monitoring since 1999, and started re-building partnerships and establishing new ones within and outside the region. Countries outside this core network have begun to establish their own monitoring programs, such that there are now 8 countries with coral reef monitoring programs, leaving only Myanmar without monitoring in ASEAN (Association of Southeast Asian Nations).

This assessment highlights the urgent need for an in-depth and extensive review of all coral reef monitoring efforts since the late 1970s, in an attempt to establish a regional standardisation of methods, data archiving, analysis, interpretation and reporting. There is a critical lack of effective coordination in SEA, even though the region is the centre of global coral reef biodiversity. All countries in ASEAN are currently making this call, and it is accompanied by





a strong commitment to work together as a regional team. The new energy that is emerging within the region provides hope for the conservation and improved management of coral reefs in SEA.

**100 Years ago:** Virtually all reefs were healthy with normal fish populations, and high diversity and abundance of reef organisms. Pressure on the reefs was low, and any pressure was isolated and concentrated around population centres.

**In 1994:** Coral reefs in Southeast Asia showed severe degradation, with experts estimating about a 20-fold decrease in coral reef condition from 100 years ago. Coral reef monitoring had been ongoing for almost 10 years in some countries, and monitoring data showed that only 3% of the reefs surveyed in SEA had live coral cover of more than 75%, and reefs with less than 25% cover had increased to almost 30%. There were many MPAs, but almost all were ‘paper parks’.

**In 2004:** Coral reef monitoring slowed from 1994 to 1998 in many countries, but increased again following the 1998 global mass bleaching event which raised awareness on the need for improved coral reef management. Monitoring programs improved and expanded, but a lack of sufficient expertise was still a concern in many countries. Coral reefs continued to show an overall decline, with a few exceptions. The greatest declines were in the Philippines, Vietnam, Malaysia and Singapore.

**Predictions for 2014:** The future of coral reefs in SEA is not very promising, with even the optimistic estimates not expecting coral cover to return to the ‘early’ levels even if management

measures are improved, implemented and enforced. Slight improvements in reef condition may be seen in well-managed MPAs, but the possibility of future bleaching and other natural events may halt the possible recovery. The pessimistic estimates follow the 'business as usual' scenario, with little or no improvements in management, and possibly further declines in coral cover and reef health, with further collapses in fish stocks.

## INTRODUCTION

Southeast Asia (SEA) is a region of high biological significance, as it contains some of the most extensive coastlines and diverse coral reefs in the world, with Indonesia, Malaysia and the Philippines (together with Papua New Guinea) forming the centre of global coral diversity; the Indo-Malayan Triangle. Reef fish diversity also follows a similar trend, with more than half of global reef fish species found in SEA. The potential economic value of well-managed coral reefs in SEA is estimated at 42.5% of the global total of US\$29.8 billion attributed to coral reef values. The potential value of coral reef fisheries is 38.5% of the global total of US\$5.7 billion, while the potential value of tourism is 50% of the global total of US\$9.6 billion. This reflects the continued high dependence of SEA countries on coral reefs for food security and increasing tourism-related revenue.

Management of coral reefs has improved since 2002, resulting from more active governance and better management of MPAs in several SEA countries. However, gaps in the management of existing MPAs in many countries are still apparent, with many MPAs lacking the resources necessary for effective implementation of management measures. The ICRAN (International Coral Reef Action Network) 'Lessons Learned' project implemented in 2001 has contributed to increased awareness and better management of the selected MPAs.

Another critical initiative was the 2002 World Commission on Protected Areas (WCPA) SEA Marine Working Group meeting, which developed the 'Regional Action Plan to Strengthen a Resilient Network of Effective Marine Protected Areas in Southeast Asia: 2002-2012'. This developed a partnership between The Nature Conservancy and NOAA (U.S. National Oceanic and Atmospheric Administration) as a 'comprehensive and collaborative effort intended to coordinate, guide and implement existing and new plans of action related to the strengthening and networking of representative MPAs in SEA'. This called on all stakeholders to support the Regional Action Plan and ensure effective implementation by 2012, to coincide with the World Summit on Sustainable Development objective of a global network of MPAs.

Significant progress has been made to improve conservation in the Sulu-Sulawesi Marine Ecoregion (SSME), with a Biodiversity Vision formulated in 2001. The vision was based on: biodiversity conservation; maintenance of productivity to sustain human needs; and stakeholders' participation in management across boundaries (i.e. cultural and political). An Ecoregion Conservation Plan (ECP) was developed in 2003 to involve government, NGOs (represented by WWF), and other stakeholders in regional conservation efforts.

Another stimulus was the appointment of a GCRMN regional coordinator in early 2004, resulting in the launching of a network identity (SEACORM Net - Southeast Asia Coral Reef Monitoring Network) and a website. The network was strengthened when national monitoring coordinators participated in the 10<sup>th</sup> International Coral Reef Symposium in Okinawa, Japan using support from the Japanese Ministry of the Environment (through the Japan Wildlife

*Basic demographic statistics of Southeast Asian coral reef countries compared to the global values.*

Coral Reef Statistics	Global	Southeast Asia	SEA % of Global
Coral reef area in km <sup>2</sup>	284,300	91,700	32.3
Coral diversity	approx 800	>600	>75
Reef fish diversity	approx 4000	>1300	>33
Potential economic value of well managed coral reefs (US\$ billion)			
Sustainable Coral Reef Fisheries	5.7	2.2	38.5
Coastal Protection	9.0	5.0	55.5
Coral Reef Tourism/Recreation	9.6	4.8	50.0
Biodiversity (e.g. pharmaceuticals)	5.5	0.5	9.0
<b>Total</b>	<b>29.8</b>	<b>12.7</b>	<b>42.5</b>

Research Center). Southeast and East Asian GCRMN Node participants discussed wider East Asian regional collaboration and the production of a comprehensive Status of East Asian Coral Reefs report in early 2005. The Symposium helped progress this regional report, based on national reports prepared using a standardised reporting template.

**GEOGRAPHIC REEF COVERAGE AND EXTENT**

SEA contains 11 countries, 10 with coral reefs plus the land-locked Laos. East Timor, the world’s newest democracy, has been excluded from this report as information on the coral reef status is currently unknown.

Total coral reef area is almost 100,000km<sup>2</sup>, being almost 34% of the world’s total coral reef area, with all major reef types represented within the region. Indonesia and the Philippines are large archipelagic nations with extensive coastlines and 75% of the region’s coral reefs, whereas Cambodia, Singapore and Brunei combined have less than 0.5% of the regional total.

**STATUS OF CORAL REEFS IN SOUTHEAST ASIA - PAST, PRESENT AND FUTURE**

This 2004 report differs from those in 2000 and 2002 in that it adopts a more regional approach, rather than focusing on individual country status. The aim is to provide a wider regional picture on outlooks and trends. A major obstacle is that the data and information are heterogeneous, therefore a standardised reporting format has been attempted to clarify the regional status. The data standardisation, however, does not permit direct comparisons between countries on specific themes and some statistics may over-represent the status in some countries, and under-represent it in others. By 2006, comparisons at regional and global scales will be facilitated through efforts to provide all countries in the GCRMN with easy to use, and standardised reporting and analysis tools.

Coral reefs in Southeast Asia are the most biologically diverse and productive reef systems in the world, but are also the most threatened and damaged reefs, with unprecedented rates of coral reef destruction from anthropogenic pressures accelerating over recent decades. Prior to 1970, there were few quantitative reports and publications of the extent, condition and status of the coral reefs. The assessments of early coral reef status is drawn from the observations

*The amount of coral reef area in SEA varies considerably between countries.*

	Brunei	Cambodia	Indonesia	Malaysia	Myanmar	Philippines	Singapore	Thailand	Vietnam
Coastline Length (km)	269	435	95,181	9,323	14,708	36,289	268	2,614	11,409
Coral Reef Area (km <sup>2</sup> )	210	<150	51,020	3,600	1,870	25,060	<100	2,130	1,270
Coral Reefs Present	Fringing, patch, atoll	Fringing, patch	Fringing, atolls, barrier reefs	Fringing, patch atolls	Fringing, patch	Fringing, atolls, barrier reefs	Fringing, patch	Fringing, patch	Fringing, patch

and reports of early explorers and anecdotal observations from people with experience in these coral reefs areas.

**Around 1900**, the coral reefs throughout SEA were mostly in pristine condition. The words of the English naturalist Alfred Russell Wallace attest to this. He visited Ambon, Indonesia in the mid-1800s and wrote: “The bottom was absolutely hidden by a continuous series of corals, sponges, actiniae, and other marine productions, of magnificent dimensions, varied forms and brilliant colours”. Those reefs are now severely degraded; heavily polluted and damaged by bomb fishing. Most of the people in SEA were thinly spread along the extensive, and virtually undisturbed, coastlines, living by subsistence and simple trading. There was minimal coastal development and that was concentrated around the emerging city-centres. Fishing pressure was not high, and the methods were largely non-destructive. Thus, most coral reefs would have probably looked like the pristine reefs found in a few areas today, in clear waters with high diversity and abundance of corals and fish e.g. Bunaken National Park or Layang-Layang in the South China Sea. At least 60% of all coral reefs in SEA were believed to be in excellent condition 100 years ago, with live coral cover exceeding 75%, and reefs with less than 25% live coral cover did not exceed 10% of the total.

The countries of SEA began an economic and population boom in the second half of the 20<sup>th</sup> century with rapid growth and development in all sectors of society and the economy. Population growth expanded from 178 million in 1950, to 321 million in 1975, to 522 million in 2000. While there was rapid modernization and development, poverty still remained prevalent with most countries classed as ‘developing’. Modernization also brought more efficient ways to harvest resources and this led to unregulated over-exploitation and, frequently, serious degradation of ecosystems. As catches diminished, more and more destructive methods of harvesting emerged in the 1970s and 1980s, like bomb and cyanide fishing, thereby accelerating the destruction of coral reefs.

**By 1994**, the proportion of coral reefs that were seriously deteriorated was probably 20 times more than the levels for 1900; this was revealed after 8 years of coral reef monitoring. These showed that 3% of the few reefs surveyed in SEA had live coral cover of more than 75%, and reefs with less than 25% cover had increased to almost 30%.

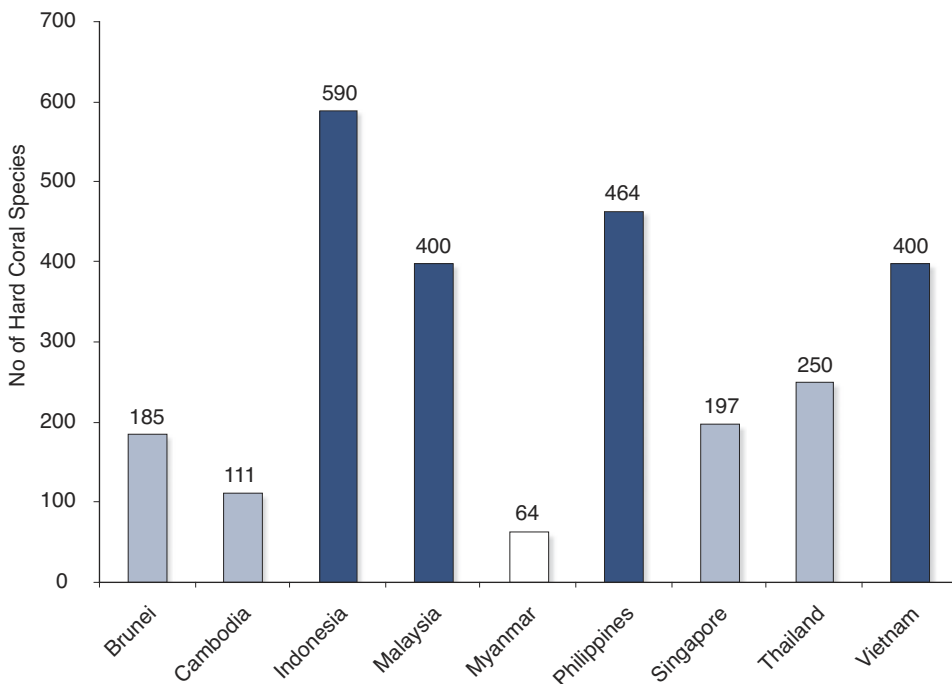
**By 2004**, there were more coral data for assessments of reef condition and these showed a slight improvement for reefs with an increase from 3% in 1994, to 9% of reefs with more than

75% live coral cover in 2004. However, the general downward trend of degraded reefs continued with decreased health and coral cover. The greatest declines between 1994 and 2004 were in the Philippines, Vietnam, Malaysia and Singapore. Thailand showed a mixed pattern, with improvements on some reefs and deterioration in many others within the Gulf of Thailand, and relatively unchanged status on Andaman Sea reefs. Indonesia was the only country that showed improvements across the board, with reef condition improving in all categories.

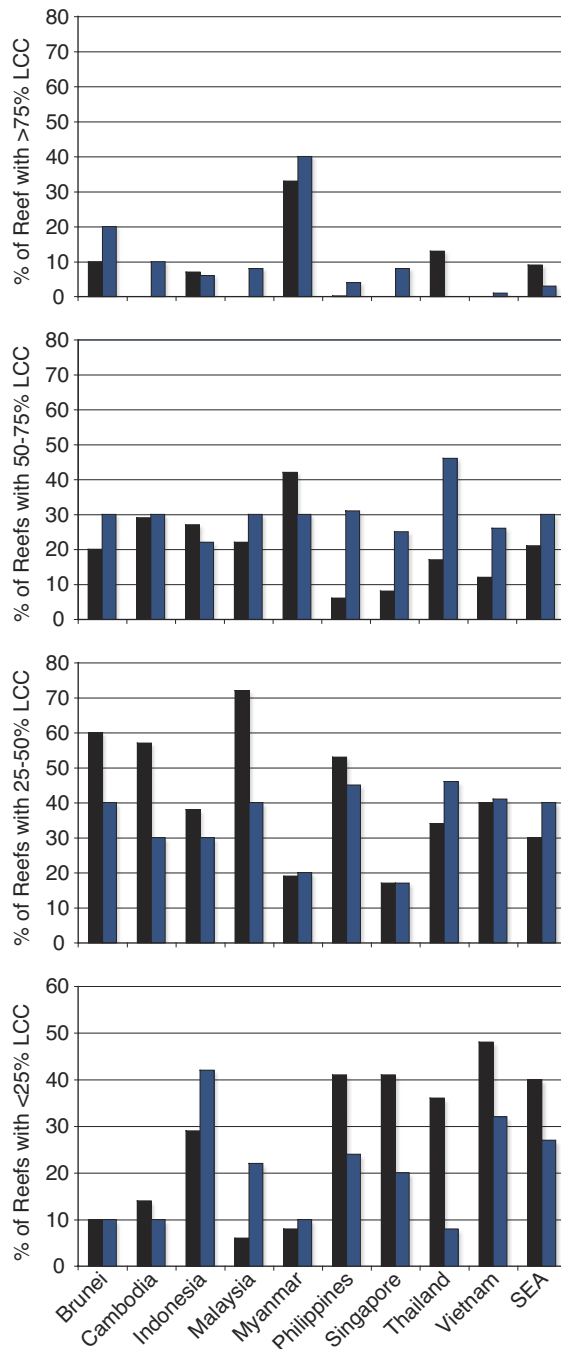
**Projecting 10 years from now to 2014**, optimistic estimates do not show coral cover returning to the early values even if management measures are improved, implemented and enforced. The pessimistic estimates follow the ‘business as usual’ scenario, with no improvements in management, and possibly further decline in coral cover.

**Brunei**

There is little coral reef monitoring information for Brunei, despite coral reef monitoring being considered an ongoing activity under the Department of Fisheries and Universiti Brunei Darussalam. The most recent information on coral reef status is from a 1992 publication, which reports 185 hard coral species. Coral reef condition was considered to be good to fair, with at least 50% of reefs having more than 50% live coral cover. The condition of the reefs in Brunei is not expected to have changed, as pressures on the reefs have not been high during the last decade.



*Estimates of hard coral species indicate that 50% to 75% of the global total occur in four Southeast Asian countries*



*Changes in percent coral cover between 1994 (dark bars) and 2004 (light bars) show that coral reefs in Southeast Asia were already in poor condition by 1994, and deteriorated further by 2004. 1994 is an indicative year with data extracted from available survey data from 1992-1994; similarly 2004 data are estimates drawn from 1999-2004 data. LCC - live coral cover; SEA - Southeast Asia combined.*

## **RAPID BIODIVERSITY ASSESSMENT OF WAKATOBI, CENTRAL INDONESIA:**

The Wakatobi Marine Park reefs are between the Banda and Flores Seas, southeast Sulawesi where circulating and seasonally changing currents bring in large amounts of coral reef larvae that facilitate fast recovery after disturbance. There are also cool water upwellings from the south, which probably protect the area from coral bleaching events. These reefs were formally known as the Tukang Besi Islands and are already targeted as an MPA. A Rapid Ecological assessment (REA) was conducted by TNC in 2003 to assist in the revision of management and zonation plans. The reefs were surveyed at 33 stations covering most of the park, with the exception of far southeastern and northeastern atolls. They recorded 396 species of hard (hermatypic scleractinian) corals with an average of 124 species per station in an area of relatively low habitat diversity. They also catalogued 10 species of non-scleractinian hard coral species and 28 soft coral genera were recorded. These numbers confirm the position of Wakatobi near the centre of high coral biodiversity. There was widespread, but not severe, coral damage mostly from fish bombing, crown-of-thorns starfish and coral bleaching. Poison fishing was probably practiced in the area, but there was no clear evidence. The reefs were in relatively good health, probably because there is such a large area to provide larvae and few major disturbances in the last decades. From: Lida Pet-Soede and Mark Erdmann.

### **Cambodia**

Coral reef monitoring in Cambodia is a recent activity, with the first surveys starting in 2000. So far, only one data set for each monitoring site is available, so there is no trend information. To date 111 hard coral species have been identified with average live coral cover for the whole coastline ranging from 23% to 58%.

### **Indonesia**

The high biodiversity is evident with 590 hard coral species catalogued, including more than 480 species in Eastern Indonesia. More reefs are being monitored under the COREMAP (Coral Reef Rehabilitation and Management Program) program which indicates that overall reef condition has been showing improvement year on year since 1999, with a definite shift from reefs with less than 25% to reefs with 25-50% live coral cover.

### **Malaysia**

Extensive coral reef survey data exist for Malaysia, with the earliest records from 1977, but much of these data are unreported and dispersed among institutions. Efforts are currently being made to collate and analyse all existing monitoring information. To date, more than 350 hard coral species have been recorded and preliminary analyses of monitoring data indicate that reefs in Eastern Malaysia are in much better condition than those of Peninsular Malaysia. Overall reef condition in Malaysia shows that almost one third of the reefs have between 25-50% live coral cover, and very few reefs with more than 75% live coral cover.

### **Myanmar**

This is the only country in the region without a coral reef monitoring program. Government officials responsible for coral reefs are keen to establish coral reef monitoring, but they lack



## RAPID BIODIVERSITY ASSESSMENT OF SANGIHE-TALAUD, NORTHEAST INDONESIA

Another Rapid Ecological Assessment was undertaken by The Nature Conservancy in the Sangihe-Talau archipelago; a chain of islands off Northeast Sulawesi, Indonesia stretching towards the Philippines. This assessment provided few encouraging results to designate this area as MPA status. They surveyed 19 sites above water, and 53 sites by scuba or snorkel over 4 weeks in 2001. In most areas, there was little reef development although 445 hard coral species were found mostly growing on volcanic rock. The exceptions were Pasige reef, and some sites in Eastern Kerakelong, Nanusa where there were true reefs. This coral diversity was comparable to Milne Bay in Papua New Guinea (379 species), the Great Barrier Reef, and Komodo National park (253 species), however, the average species count per site of 100 was much lower. There was extensive damage from coral bleaching and bomb fishing in the Nanusa Archipelago, where over 60% to 80% of the corals in most of the sites were recently dead. The level of human impact was also high, with evidence of deforestation on the islands and severe over-exploitation of the reef fish populations. Heavy fishing activity was observed everywhere. Some areas (East coast of Talau) were also affected by siltation, and turtles are under severe pressures through egg collection and hunting of the adults for meat and shells. The REA teams reported serious and immediate threats to biodiversity, with high biodiversity areas fragmented and dispersed. Thus there are no contiguous, large areas that are likely candidates for an intensive marine conservation program. A more detailed REA may find localities that are suitable candidates for smaller MPAs, as the attitude of the local communities towards conservation is quite positive, and they may take the opportunity to assist in the management of smaller MPAs.

the capacity. Current information on coral reef status in Myanmar is limited to 2 expeditions by Reef Check Europe between 2001 and 2003 to western areas of the Mergui Archipelago. Only 65 hard coral species have been catalogued, which is almost certainly an underestimate. Reef Check reports that the reefs in the southern Mergui Archipelago are relatively healthy, with about 75% of reefs having more than 50% live coral cover.

### **Philippines**

They have identified 464 hard coral species, which amounts to about half of the global reef-building coral diversity. Current data suggest that the reefs are experiencing a steady decline of 3 to 5% reduction in coral cover at all sites examined. This degradation trend is corroborated with 33% of reefs in the 'poor' condition category in the 1980s increasing to nearly 40% two decades after.

### **Singapore**

Despite the small coral reef area in Singapore, hard coral diversity is relatively high, with almost 200 species recorded. Reef status in 2004 is mixed with reefs close to shore and adjacent to high coastal development and land reclamation showing clear degradation, with deeper parts of the reefs almost completely buried under sediments. Reefs further from shore and provided with the protection from nearby military bases, have shown improvement in live coral cover on the shallow reef areas.

### RAPID BIODIVERSITY ASSESSMENT OF BANDA ISLANDS, EAST INDONESIA

The rapid biodiversity assessment of the Banda Islands, Eastern Indonesia, was carried out in 2002 to evaluate the possibility of listing these Islands as a Natural World Heritage Site by the Government of Indonesia. The reefs were generally in good condition, with only scattered and minor levels of damage observed. Over 300 hard coral species were recorded, which is high on such small areas of reef which consists mostly of narrow fringing reefs with no intertidal reef flat. There were 4 coral communities identified: 2 on the deep slopes; and 2 in shallower areas. Coral growth was very fast as there were few old corals seen e.g. over 100 years. There were also 500 fish species from 50 families, and the estimated fish diversity rates fifth among 32 sites in the Asia-Pacific region. This diversity is extremely high considering the small surface area of the Banda Islands and the limited range of habitats. There were many of the highly valued Napoleon wrasse (*Cheilinus undulates*) compared to the heavily exploited area of Indonesia, but the populations of large groupers (*Serranidae*) clearly showed signs of exploitation. These Islands were considered to be of great global biodiversity significance and worthy of World Heritage Listing. From: Peter Mous, TNC Indonesia, pmous@TNC.ORG

#### Thailand

Only the 1999 coral reef monitoring data are available, but these report more than 250 species of hard corals in both the Andaman Seas and the Gulf of Thailand. About 15% of the reefs in the Gulf of Thailand have more than 75% live coral cover, whereas about 25% of the reefs have less than 25% live coral cover. 2003-4 monitoring data are also available for certain sites.

#### Vietnam

The latest survey data has confirmed higher coral diversity with species numbers ranging from 300 to 350 in southern areas. Data from 2003-4 indicate that most reefs have less than 25% live coral cover.

**The perspective for 2014** is uncertain, with both optimistic and pessimistic predictions provided by regional experts. With improved regional coordination, awareness and more proactive measures implemented or planned, there is optimism that reef health will improve throughout the region, with measurable increases in the number of reefs with higher live coral cover and corresponding decreases in reefs with lower coral cover. However, if management measures do not keep pace with the rate of reef deterioration, then the future for coral reefs in SEA looks bleak, with a possible total loss of reefs with more than 75% live coral cover and an increase in the number of severely damaged and dead reefs. The effects of future El Niño and global warming leading to potential bleaching events are future threats, and could potentially have serious impacts on the coral reefs of Southeast Asia.

#### STATUS OF CORAL REEF FISH AND FISHERIES

Despite a long history of coral reef monitoring, reliable and consistent quantitative data on status of coral reef fishes are scarce for most countries in SEA, with the Philippines being the exception. Fish biodiversity and distribution patterns are well documented, but reef fish

## INDONESIAN MARINE PROTECTED AREAS: EVALUATION OF FISHING GEAR

Regulation of fishing effort in Indonesia is difficult, as the local fisheries agencies do not have adequate resources to monitor and collect information on effort, numbers, and distribution of fishing communities. The major gears used in Indonesia are purse seine and drift nets, but a variety of other gears are used on coral reefs, including hook and line, spearguns, hand spears, traps, gill nets, and muro-ami. The damaging practice of muro-ami is widespread throughout Karimunjawa National Park, Central Java; this involves divers driving fish into a large seine-like nets set on the reef. The species selectivity and catch composition among gears showed that 204 fish species from 37 families were recorded from 187 landings. Net fisheries caught the most species (127 species per day), while hand spears caught the least number of species (14 species per day). Muro-ami fishing caught the highest numbers of fish per fisherman ( $11.2 \pm 4.4$  individuals per day) and the smallest size fish ( $28.3 \pm 0.64$  cm). Net fishers caught a mean of 12 species during a single fishing trip, while other gears caught 4-6 species. Predatory fish species caught by hand lines and gill nets had the highest (3.82 and 3.78 respectively) trophic diversity (different levels of fish on the food chain), while spear guns had the lowest (2.69). The mean trophic level of fish caught by muro-ami (3.39), suggested that muro-ami caught a wider variety of species. The high numbers of individuals and species, and low size of fish caught by muro-ami indicated it was a non-selective gear, but with high species overlap with other gear types, notably traps. Therefore, muro-ami fishing is likely to compete with other more benign gear and be unsustainable. Interviews with 119 local fishers showed that 80% supported regulations to abolish muro-ami fishing; a restriction that will reduce the catch of small fish and species overlap in selectivity among gears used. Tim McClanahan, Wildlife Conservation Society, Kenya, [tmcclanahan@wcs.org](mailto:tmcclanahan@wcs.org)

population size data are lacking for most countries. A contributing factor is poor capacity, because conducting fish visual census surveys requires high technical ability and considerable experience. Thus most countries have focused on the corals and other bottom organisms.

Reef fish diversity is high; and the reported numbers are increasing as more reef areas are assessed. However, reef fish abundance, especially for economically important species (food fish and aquarium fish), is declining on most reefs. Fewer and fewer species like the barramundi cod, the bumphead parrotfish, the napoleon wrasse and grouper are being recorded during reef surveys. Detailed information on coral reef fish for 2004 is only available for Cambodia, Malaysia, Philippines and Vietnam.

### **Cambodia**

Marine fish are primarily harvested using traps, gillnets and hook and line, however, some illegal bomb and cyanide fishing is targeting commercially important species. Juveniles and pre-adults of reef fish are also collected for grow-out in cages along the coast, where they are sold live in local markets and in markets of Hong Kong, China and Taiwan.

### RAPID BIODIVERSITY ASSESSMENT OF RAJA AMPAT, WEST PAPUA

The Raja Ampat Islands, off the northwest coast of Papua, Indonesia (near the 'bird's head' of New Guinea) have a reputation for beauty and high coral reef biodiversity; likely candidates for conservation. The Nature Conservancy and partners did Rapid Biodiversity Assessment (REAs) over 3-weeks following similar assessments by Conservation International, the University of Cenderawasih and LIPI-Oceanologi and earlier TNC assessments with the Henry Foundation and NRM/EPIQ. They surveyed the eastern and southern areas of Raja Ampat during a cruise in late 2002 in association with WWF Sahul. Focal areas of the research were marine species biodiversity and ecosystems quality, terrestrial ecosystems and threats, and socio-economic studies of local communities using the resources. These islands have one of the world's highest coral reef fish species lists, with at least 1,074 species of which 899 (84%) were observed or collected during the surveys, including 104 new records for Raja Ampat. The CI surveys reported 970 species from this area. This is the third highest count for any similar-sized location, surpassed only by Milne Bay Province, PNG (1,109 species) and Maumere Bay, Flores, Indonesia (1,111 species), which were from longer, more intense surveys. Thus the Raja Ampat total was a global record for a visual survey. Raja Ampat is also known for high diversity of hard corals with the total in the archipelago expected to be over 75% of world's known coral species. There were 488 hard corals identified during this REA, with a further 35 species awaiting identification using reference collections. There are probably 13 new species. The Raja Ampat count compares to 445 species in North Sulawesi, 379 species in Milne Bay and 347 in Kimbe Bay, PNG. The counts in 2001 and 2002 bring the total for Raja Ampat to at least 537 coral species. In addition there was high diversity of soft corals with at least 41 of the 90 Alcyonacean known genera being found. The reefs in the Raja Ampat area were in very good health, with about 33% average coral cover and no evidence of serious damaging effects like coral bleaching, recent crown-of-thorns starfish outbreaks or sediment and pollution. The REAs showed that conservation of the area is an overriding priority for the global community, especially 4 areas: the islands of eastern and southern Misool, Kofiau, Sayang and Pulau Ai, and the Wayag islands. From: R. Donnelly, D. Neville and Peter Mous, TNC Indonesia, pmous@TNC.ORG

### Malaysia

The coral reefs in Peninsular Malaysia are mostly protected as Marine Parks under the Fisheries Act (1985) and managed by the Department of Fisheries. Fishing is not allowed on the reefs within the Parks, except for non-extractive activities, and reef fisheries are currently non-existent and unmonitored. In Eastern Malaysia, heavy exploitation of coral reef fishes (and invertebrates) occurs outside of the Parks. Studies have estimated that coral reef fisheries contributed about 7.26 to 22.63 % mt to marine fish production from 1980 to 1990, but these estimates are considered under-estimates because some of the coral reef fish families (e.g. Acanthuridae, the surgeonfish, Scaridae, parrotfish) and catch taken for the live-fish trade were not considered. The live reef-fish food fish trade (and culture of *Tilapia* spp. and *Lates calcarifer*) begun in mid-1980s and generated income of valued at RM 0.35 M (USD 1 = RM 2.5) from 3,000 metric tons, in 1992. This increased to 7,000 mt, valued at about RM 0.78 M

in 1994. In 2001, the contribution of cage-culture of coral reef fishes alone was 550 mt, valued at RM 9 M.

**Vietnam**

Fish data are grouped into target fish groups, with low abundance of predatory reef fish like groupers, snappers and sweetlips in almost all coastal reefs. Only reefs in a few areas in the Gulf of Thailand (Phu Quoc, Nam Du and Tho Chu) had good to moderate densities of predators. Small fish like Pomacentrids are abundant only in the Gulf, while grazing reef fish are abundant in all areas.

**Philippines**

The most reliable data on reef fish are available from the Philippines, with calculations of derived biomass in addition to species diversity, abundance and density estimates. Reefs with 1 - 5 metric tons km<sup>-2</sup> (very low) and 5.1 to 10 mt km<sup>-2</sup> (low) are considered as over-fished; reefs with 11 - 20 mt km<sup>-2</sup> (medium) are considered as slightly or moderately fished; and those with 21 - 40 mt km<sup>-2</sup> (high category) and >40 mt km<sup>-2</sup> (very high) estimates are considered as having very minimal fishing and/or have been protected as an MPA for at least 5 years.

*There are large differences in the annual catch of marine fish and the amount produced by aquaculture in the countries of SEA. Coral reef fish constitute a large proportion of the catch.*

	Brun	Camb	Indo	Mala	Myan	Phil	Sing	Thai	Viet
No. Marine Fish Species	Unknown	520	>1,650	>1,000	Unknown	>1000	>130	>350	411
Marine Fisheries Production (x1000 mt)									
-Average Annual Catch	2	22	3,705	1,257	879	1,742	5	2,649	1,281
- Aquaculture Production	0	-	187	13	-	162	1	6	-

mt-metric tons; Brun=Brunei; Camb=Cambodia; Indo=Indonesia; Mala=Malaysia; Myan=Myanmar; Phil=Philippines; Sing=Singapore; Thai=Thailand; Viet=Vietnam

They have assessed that more than 50% of the reef sites in the Philippines, with the exception of the Sulu Sea, surveyed between 1991 and 2004 are in the very low and low categories i.e. over-fished. The high fish biomass category was more common in the Visayas and Sulu Sea areas, comprising 25.8% and 32.9% of reefs, respectively. Very high fish biomass categories were observed where there was also high species diversity, such as the South China and Sulu Sea, each containing 15% of the total reef area. These regions contain large MPAs, such as the Tubbataha Reef National Marine Park in the Sulu Seas region and many reefs in the South China Seas (i.e. Spratly Islands). Thus, the only reefs with healthy fish populations are either in MPAs or are remote with ‘political’ protection. Efforts are currently being made to use the same criteria to assess the status of coral reef fish in the rest of Southeast Asia.

Small-scale subsistence reef fishing is a major activity in most coastal communities, thus comprehensive and reliable reef fisheries statistics are not available. The only comparable data available for all countries were extracted from the EarthTrends World Resources Institute

### **PUERTO PRINCESA SUBTERRANEAN RIVER NATIONAL PARK**

The St. Paul Bay Coral Reef consists of a number of coral colonies scattered within a 2,700 hectare area in the South China Sea, adjacent the Puerto Princesa Subterranean River National Park. The bay is an important fishing area for local residents who compete with migrant fishermen from other parts of the country for access to the resources. However, the area is remote and this makes law enforcement difficult; the coral reefs have deteriorated due to destructive fishing methods. Initial plans between management and the community to establish a Marine Reserve in the entire bay started with an agreement with both parties to restrict fishing in the bay to traditional fishing methods. The Park management protects 2 292 ha of inter tidal zones, seagrass beds and coral reefs of the marine reserve out to 1 km offshore. A no-fishing policy is being implemented in the reserve, although it is not supported by any legal arrangement. The corals in the reserve are in better condition compared to areas outside in the bay, and 65 species of fish have been identified in the reserve. There are also rays, sharks and dolphins, and the Bay is a known feeding ground for the endangered turtles and dugongs. The progress of fully establishing the MPA has been hampered and delayed by the limited management resources.

website. The 2000 data indicated that the average annual catch in Indonesia is highest followed by Thailand and the Philippines. Malaysia and Vietnam catch similar tonnage, while catches in Cambodia, Brunei and Singapore were insignificant. Aquaculture production of marine fish is still low in all countries, and usually involves grow-out of wild captured juveniles.

Most coral reef fisheries are multi-gear, small-scale operations targeting many species. Different fishing methods are used to harvest a variety of marine organisms, including hookah air diving (in Vietnam), purse seine and gill nets, light fishing at night for anchovies and cuttlefish, drift nets, long lines, trawling and gleaning on tidal flats. Destructive fishing methods like bomb and poison fishing have been heavily used recently and have caused massive reef destruction. Although such methods have been banned in all countries, illegal fishing continues almost unabated in many areas.

### **MONITORING CAPACITY IN SOUTHEAST ASIA**

Current monitoring capacity within SEA countries varies greatly, with the Philippines having the longest history in monitoring and research, which started in the late 1970s. In contrast, Myanmar has no national monitoring program and there is minimal available information on the reefs, with only volunteer monitoring by Reef Check Europe providing some data. Cambodia started a monitoring program in 2000 through capacity transfer from within the region, especially from Singapore, with UNEP and Japanese Ministry of Environment funding. Efforts are underway in Brunei to initiate monitoring, with the first surveys planned for late 2004 to early 2005. National level monitoring commenced in 1998 in Vietnam through support from UNEP, Total Foundation, WWF, DANIDA, Reef Check and NOAA-USA.

Coral reef monitoring has expanded over the last 10 years in most SEA countries, with many programs being funded by national and international agencies, but predominantly through



*Coral reef monitoring capacity in Southeast Asia varies greatly from country to country.*

	Brun	Camb	Indo	Mala	Myan	Phil	Sing	Thai	Viet
National coral reef monitoring program statistics:									
1 <sup>st</sup> local monitoring program initiated	2004	2000	1986	1986	NA	1977/8	1986	1986	1998
Ongoing monitoring	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
Existing funding for monitoring	No	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
No. of permanent monitoring sites/ areas	4	7	>500	7	NA	>80	9	250	10
Estimated number of trained personnel for core monitoring methods in 2004 (including NGOs & volunteers)									
LIT (AIMS Method)	0	7	U	<20	NA	60	8	30	U
Reef Check	U	10	U	<100	NA	>250	>100	>200	U
FVS (AIMS Method)	0	0	U	<20	NA	60	2	20	U
Coral ID (Genera or Species)	3	0	U	<10	NA	15	8	25	U

U = Unknown; NA = not applicable; LIT = line intercept transect; FVS = fish visual census; ID = identification to Genus or Species level

Brun=Brunei; Camb=Cambodia; Indo=Indonesia; Mala=Malaysia; Myan=Myanmar; Phil=Philippines; Sing=Singapore;

international assistance. Greater effort is required within the region to highlight the importance and significance of monitoring to government agencies, to ensure that more national resources are provided for effective long-term monitoring and data management. This is essential for long-term management of the coral reefs.

The number of permanent coral reef monitoring sites surveyed in 1994 compared to 2004 were in a wide range: 0 to 0 in Myanmar; 10 to 0 in Malaysia; 0 to 4 in Brunei; 6 to 6 in Singapore; 0 to 7 in Cambodia; 3 to 11 in Vietnam; 10 to 36 in Philippines; 420 to 250 in Thailand; and 340 to 583 in Indonesia. Thus monitoring has increased in Indonesia, the Philippines and Vietnam. The amount of monitoring, however, bears little relationship with the area of coral reefs, with both Indonesia and the Philippines having enormous reef areas. Most countries reported a lack of trained people for monitoring, with a range of 10-60 people in each country. The only major increases in recent years are in those trained in Reef Check methods. Few, however, have sufficient training in coral and fish identification.

**Brunei**

Routine monitoring is the responsibility of the Department of Fisheries in Brunei, but a lack of capacity and commitment has resulted in minimal monitoring over the past 8 years. Previous reports on coral reef status date to 1992 only; however, the Universiti Brunei Darussalam is planning a monitoring program to start in 2004 at 4 sites.

**Cambodia**

The first monitoring started in 2000 with training of Department of Fisheries staff at 7 sites, which were monitored using both Reef Check and Line Intercept Transect methods for coral, invertebrates and fishes. The data in this 2004 report are the first on coral reef status from Cambodia and more training of volunteers and government staff is planned.



## RAPID MARINE BIODIVERSITY

### ASSESSMENT OF RAJA AMPAT ISLANDS, INDONESIA

The Marine RAP survey by Conservation International in 2001 of the Raja Ampat Islands assessed 45 sites in an area of approximately 6,000 km<sup>2</sup>, including the coral reefs of the Dampier Strait between northern Batanta and Waigeo. They found:

- *Corals*: 456 species of hard corals; more than half of the world's total and richer than any other comparable area;
- *Molluscs*: comparatively high diversity with 699 species, surpassing previous RAP surveys in Papua New Guinea and the Philippines;
- *Reef Fishes*: 828 fish species, raising the total for the islands to 972 species. By extrapolating this based on 6 key indicator families, they estimate that there could be at least 1,084 species in the area;
- *Reef Fisheries*: 196 species are targets for reef fisheries, and the mean total biomass for sites in the Raja Ampat Islands is considerably greater than other surveyed areas, including Milne Bay Province, PNG, Togean-Banggai Islands 1998 (Indonesia), and Calamianes Islands 1998 (Philippines);
- *Coral Condition*: 60% of the surveyed reefs were in good to excellent condition based on coral and fish diversity, benthic community structure and evidence of damage and disease. The major threats were destructive fishing and siltation from numerous logging activities;
- *Community Issues*: The community liaison team visited 22 villages and identified that the villagers were in urgent need of income; they lacked knowledge of conservation law and had little awareness of conservation needs. The high prices for marine resources relative to traditional community incomes provided strong incentives for illegal overuse of marine resources.

The findings from this survey by Conservation International and others helped to catalyse local communities, local, national and international governmental and NGOs to develop a strategic conservation plan for this region. The survey was supported by the David and Lucile Packard Foundation, Henry Foundation, and the Smart Family Foundation Inc. Participants came from the University of Cenderawasih, Papua State University, Indonesian Institute of Sciences, Research and Development Center for Oceanography and CI-Indonesia, as well as the Australian Institute of Marine Science, Western Australian Museum, and CI. The results are available in the RAP Bulletin #22. From: Irdez Azhar Raja Ampat, Corridor Manager, Conservation International Indonesia – Papua Program, Sorong 98413, Papua – Indonesia.

## Indonesia

Monitoring in Indonesia has been coordinated under COREMAP (Coral Reef Rehabilitation and Management Program) since 1994. In addition, other international agencies also conduct coral reef monitoring e.g. Project Wallacea in Wakatobi, TNC in Komodo and WWF in Bali and Karimunjawa. The data in this report are from COREMAP, which has increased capacity and resources for coral reef monitoring, with 648 established sites across Indonesia, almost double the 340 sites in 1994, with 582 sites monitored in 2004. This strong, localised program is providing training and coordination across the archipelago.

**Malaysia**

Malaysia's coral reef monitoring program is coordinated by several agencies. In Peninsular Malaysia, the Department of Fisheries (DoF) staff conducts regular monitoring at limited areas in Marine Parks. In addition, DoF works with local universities and international agencies (CCC, WWF), which have monitoring programs of their own. In Eastern Malaysia, the DoF-Sarawak, monitors the reefs in Northeast and Southwest Sarawak with universities and the private sector, while in Sabah, Pulau Tiga Marine Park, Tunku Abdul Rahman Park, Turtle Islands Park, and Tun Sakaran Park are monitored by Sabah Parks. In addition, two other coral reef areas are being protected and monitored by other governmental agencies: 1) Sugud Islands Marine Conservation Area by Sabah Wildlife Department enactment; 2) Sipadan Island by National Security Department. Sabah Parks works with local and international universities, while the Sabah Wildlife Department works with the private sector. Data from coral reef monitoring over the last 8 years are substantial, but the biggest obstacle that faces Malaysia is the coordination of the data. Currently, all agencies, organisations and institutions manage their own data, with no centralized coordination for data archival or analysis. Efforts are currently being made by the DoF to establish a national database to archive all data from Malaysia. Data in this report are derived from a variety of data sources, collated towards the end of 2004. This is not a comprehensive or representative survey. A more detailed synthesis of the existing data is currently being conducted.

**Myanmar**

There is no national coral reef monitoring program in Myanmar, and data reported here were derived from two Reef Check Europe expeditions to the southern Mergui Archipelago.

**Philippines**

Coral reef monitoring is coordinated by the coral reef information network of the Philippines (PhilReefs), with the Marine Science Institute of the University of the Philippines serving as the coordinating agency responsible for GCRMN reporting. There is also active monitoring by several local and international agencies and organisations, and data reported here are from all these agencies.

**Singapore**

Most coral reef monitoring and coordination has been through the National University of Singapore, until early 2004. Now the National Parks Board is establishing a national coral reef monitoring program linking those of the University and other volunteer groups and organisations. This will include the establishment of a National Biodiversity Reference Center, which will also be involved in capacity building.

**Thailand**

The Department of Marine and Coastal Resources (DMCR) is the coordinating body for coral reef monitoring in Thailand, but there is little effective coordination to collate the extensive data held by many organisations. Unfortunately the data in this report were derived from 1999 statistics, hence do not adequately reflect the status of coral reefs in Thailand in 2004.

**Vietnam**

The Institute of Oceanography in Nha Trang conducts and coordinates coral reef monitoring, and facilitates data management and reporting.

## THREATS TO CORAL REEFS IN SOUTHEAST ASIA – PAST, PRESENT AND FUTURE

### ‘Reefs at Risk’ Threat Estimates

The 2002 Reefs at Risk (R@R) assessment in SEA by the World Resources Institute estimated that 88% of the reefs were at ‘medium’ to ‘very high’ risk of damage. Among the greatest threats were over-fishing and destructive fishing estimated to be threatening 64% and 56% of the reefs respectively. These data indicate significant socio-economic and governance issues related to the high dependence of coastal communities on reef resources, and the increasing market demands of growing economies. Coastal development impacts are more focused, especially in the Philippines, Singapore, Thailand and Vietnam, where there are rapid expansions.

A panel of regional scientists revised the 2002 R@R assessment and threat indices in 2004. There were slight (1-5%) to moderate (5-15%) increases in all 5 key indices, especially coastal development, marine-based pollution and sedimentation (Cambodia, Indonesia, Malaysia, Philippines, Singapore, Thailand, Vietnam), with lesser increases in over-fishing and destructive fishing (Cambodia, Indonesia, Philippines, Vietnam). The leading threats in 2004 continued to be over-fishing and destructive fishing, with coastal development starting to become a greater threat.

*The opinions of local experts were compiled on possible changes in the 5 R@R threat indicators in SEA in the next 10 years (to 2014) compared to the 2002 analysis performed by the World Resources Institute. Most of the threats are predicted to remain the same or increase in all countries, with no indications of improvements.*

	Brun	Camb	Indo	Mala	Myan	Phil	Sing	Thai	Viet
Coastal Development	⊘	↑	⊘	↑	Unknown	↑	↑	⊘	⊘
Marine-Based Pollution	⊘	↑	⊘	⊘	Unknown	↑	⊘	⊘	⊘
Sedimentation	⊘	↑	⊘	⊘	Unknown	⊘	⊘	⊘	⊘
Over-fishing	⊘	Unknown	Unknown	⊘	Unknown	⊘	⊘	⊘	⊘
Destructive Fishing	⊘	Unknown	Unknown	⊘	Unknown	⊘	⊘	⊘	⊘

↑ - increasing threats; ⊘ - no observable change; Unknown – no expert opinion available  
 Brun=Brunei; Camb=Cambodia; Indo=Indonesia; Mala=Malaysia; Myan=Myanmar; Phil=Philippines; Sing=Singapore; Thai=Thailand; Viet=Vietnam

### Measurable Threats

Quantitative data on measurable threats, like crown-of-thorns starfish (COTS), bleaching, coral damage due to bomb fishing, ship groundings, anchor damage, storms and sedimentation are not readily available, with most reports being predominantly anecdotal. The 1998 mass bleaching event was serious for many reefs around the world, but did not have a severe impact on reefs in the Eastern Indian Ocean and the South China Sea (i.e. west coast Malaysia, Thailand, Myanmar and the Andaman Islands). There has been no repeat of the 1998 mass coral bleaching event, although several smaller and dispersed events were reported over the past 6 years in Indonesia, Philippines, Thailand and Malaysia. There is however, a possibility that future El Niño events may have more severe impacts on the reefs of Southeast Asia.

### NINH THUAN, VIETNAM – ICRAN TARGET SITE

Coral has been used to make cement in Ninh Thuan since 1979, with the Phuong Hai Cement Company mining dead coral on land. Supplies dwindled, so they started mining corals off My Hoa beach. When the local villagers saw the damage done to a 1 hectare plot of coral, they protested by lying in front of the mining trucks. The community had been made aware of the need to protect marine resources by a WWF Sea Turtle Conservation project. Furthermore, when Ninh Thuan was selected as an ICRAN target site in 2002 (Box p 272) the level of awareness increased even more. Coral exploitation in My Hoa was stopped by the Provincial People's Committee and is strictly controlled by the local community.

“Being part of ICRAN has changed my thinking on how the reefs in our province should be managed. It has also unified local government agencies and ministries for the first time and provides the central core for other projects which are related to coral reefs,” said Tran Phong, Director of the Ninh Thuan Department of Science, Technology and Environment. The Ninh Thuan Provincial authorities have strong determination to protect their coral reefs and in consultation with local communities are preparing their own regulations for protection. A legislation signing ceremony was held in September 2004. The advice of community elders, that was previously ignored but reinforced in the ICRAN project, is now influencing the fishermen who have formed volunteer patrols to protect their coral reefs and fisheries.

Capacity building has been a special feature of the ICRAN project with 10 training workshops on coral conservation and socio-economic impacts for more than 900 participants, and exchange visits with other successful MPAs like Apo Island (Philippines). A Disney Wildlife Conservation Fund project on coral mapping for management is now developing user-friendly GIS maps for managers and policy makers. The ‘Coral Reef Monitoring for Management’ manual has been translated into Vietnamese and many other communication materials have been designed specifically for the children and the community. Two communes have established their own reef management programs and established volunteer teams for coral reef protection and awareness raising, including assessing alternative income opportunities, legislation and management practices. Algal aquaculture was trialled unsuccessfully at two sites, but has provided valuable insights for future aquaculture and possible community-based eco-tourism ventures. The community and WWF have started monitoring corals at 23 sites in 18 coastal fringing reefs in the Nui Chua Nature Reserve. They identified 307 coral species, with 46 new distribution records for Vietnam. These coral reefs are quite different from those further north (Hon Mun MPA, Na Trang Bay) and south (Con Dao National Park), indicating that the Ninh Thuan area will be a valuable component of a national MPA network. Contact: Kristian Teleki, [icran@icran.org](mailto:icran@icran.org), [www.icran.org](http://www.icran.org)

Outbreaks of COTS have been reported in several countries, including significant damage to the reefs around Tioman Island, Malaysia and to several reefs in Indonesia, the Philippines, Thailand and Vietnam. Increased sedimentation was reported to be a problem in many countries, with reports of decreasing water visibility along coastal areas, which was attributed to increasing rates of development, dredging and reclamation.

### CORAL REEF MANAGEMENT STATUS IN SOUTHEAST ASIA

Coral reef management in Southeast Asia has received poor press coverage for over a decade due to weak and ineffective management that is failing to reverse the alarming decline in reef health and resources. A comprehensive assessment of the status of MPAs of 9 of ASEAN has evaluated the threats to the marine environment, the status of the resources and the degree of management needs, along with recommendations for priority action. Over the last 15 years, there has been a proliferation of MPAs established and proposed in the region e.g. in 2002, over 630 declared and 185 proposed MPAs that included substantial marine areas and mangrove forests were identified. Philippines has the most, accounting for almost 80% of the total, and Indonesia, with the largest area of coral reefs, has only 29 declared and recognised MPAs. There are none in Myanmar.

Although the establishment of MPAs reflects growing awareness among governments of the need to solve the problems of environmental degradation, e.g. 88% of all coral reefs are under threat; good management and enforcement measures rarely accompany MPA declarations. Management in most MPAs remains inadequate, with 46% of declared MPAs having no or very little management, and only 10-20% are considered to be managed effectively. All these MPAs contain less than 11% of the coral reef area of SEA, with the exception of Thailand where 50% of the reefs are in reserves. More effort is required to strengthen planning and management of existing MPAs, and to establish new MPAs to cover areas of high conservation value. Coordination and sharing of experiences among the network of MPAs needs to be heightened, with a strong role envisaged for the ASEAN Regional Centre for Biodiversity Conservation (ARCBC) and the ASEAN working group of the World Commission on Marine Protected Areas (WCMAPA), United Nations Environment Program (UNEP) and SSME-Network of MPAs.

*Although there are many MPAs in Southeast Asia, the % of coral reefs within the MPAs is generally low and few MPAs have effective management.*

	Brun	Camb	Indo	Mala	Myan	Phil	Sing	Thai	Viet
Total MPAs - Declared	6	1	29	16	4	500+	2	23	22
Additional MPAs - Proposed	2+	2	14+	1	1	150+	4	3	7
% Reefs Within MPAs	0	Unknown	9%	34%	2%	1%	0	50%	11%
% MPAs with good management	0	0	<3%	18 %	0	10%	50%	18%	8%

Brun=Brunei; Camb=Cambodia; Indo=Indonesia; Mala=Malaysia; Myan=Myanmar; Phil=Philippines; Sing=Singapore; Thai=Thailand; Viet=Vietnam

### PARADISE ON EARTH – CON DAO, VIETNAM

Con Dao is one of the few remaining places in Vietnam where endangered animals like dugong, turtles, and dolphin occur, and where the biodiversity on the coral reefs is comparable with the best tourism destinations in Southeast Asia. Con Dao was declared a protected area in 1984 and a national park in 1993 to protect 20,000 ha; 14,000 ha of marine ecosystems, including mangroves, coral reefs, and seagrass beds, and 6,000 ha of land on 14 islands, surrounded by a 20,500 ha marine buffer zone. Since 1995, WWF has trained the park staff and local communities to conserve Con Dao's marine biodiversity. They have held technical workshops including hands-on experience with conserving marine turtles and dugong, marine biodiversity and environmental education, as well as study tours to Thailand, Malaysia, and the Philippines. Con Dao is a leading national park for marine biodiversity in Vietnam, and the park staff are training in other provinces, and are drawing on their staggering breadth of experience with their resource to assist with tackling problems and challenges raised during international conferences. Con Dao is being used as an example to demonstrate the importance of conservation for many Vietnamese. "I have never seen anything this beautiful. How valuable and wonderful are the things granted to us by nature. I am sure that snorkeling to see the coral reefs can be promoted on Phu Quoc Island, and will definitely attract a lot of tourists. This will both ensure the conservation of marine biodiversity and help the local economy," said Nguyen Hong Cuong, head of the District Department of Agriculture, Forestry and Fisheries of Phu Quoc Island District. The vice-chair of the People's Committee of Van Don District in Quang Ninh Province, Nguyen Hai Ly said, "Before we used to feel puzzled and lost because we thought that nature conservation conflicted with the needs of local people who in our coastal areas rely mainly on marine natural resources. But now we already see the solutions. We will definitely invite Con Dao National Park staff to our district to help us replicate their marine biodiversity conservation model." From: Keith Symington Marine Program Coordinator, WWF Indochina, keith@wwf.org.vn

Several new MPAs, such as Hon Mun and Cu Lao Cham, have been established in Vietnam by the Ministry of Fisheries, and others that were previously designated for terrestrial conservation have been amended to include conservation of coral reefs and related ecosystems e.g. Con Dao, Nui Chua, Phu Quoc, Cat Ba National Parks and Ha Long World Heritage site. However, the effectiveness of marine management is limited due to the low capacity for marine conservation. Only Hon Mun and Cu Lao Cham MPAs, and Con Dao National Park have implemented biodiversity surveys and zoning for resource use within the management plan. Several provinces and cities are preparing management plans for their coral reefs. The model for effective coral reef management is being developed in Ninh Hai district (Ninh Thuan) province where attempts are being made to resolve economic conflicts between different stakeholders using and conserving the reefs. Plans to establish small-scale 'no-take' zones are being developed for Ninh Hai and Van Phong Bay as the first-step towards more effective measures for integrated management of coral reefs.

In the Philippines, over 600 MPAs have been established, but only 10% of these were assessed as being managed effectively, primarily due to ineffective enforcement and confusion in designating



who is responsible for enforcement of MPAs under national programs. The management of many MPAs has been handed over to local community organisations, but monitoring is still lacking in most MPAs.

### **GOVERNMENT LEGISLATION AND POLICY ON CORAL REEF CONSERVATION IN SOUTHEAST ASIA**

Numerous policies, programs and guidelines have been formulated over the last two decades for environmental conservation, but these are mostly 'soft' instruments like Memorandums, Declarations, and Resolutions. The 'ASEAN Declaration on Heritage Parks and Reserves' in 1984 provided guidelines and criteria to: select and establish ASEAN Heritage Parks; select ASEAN Marine Heritage Parks; and declare national MPAs. A preliminary list of ASEAN Heritage Parks, including MPAs, has been drafted but there are no current management plans.

The 'ASEAN Strategic Plan of Action on the Environment' (ASPAE) was established following recommendations of Agenda 21. Under the plan, several programs and strategies were drafted to address issues of biodiversity conservation and sustainable use, and protection and management of coastal zones and marine resources. The ARCBC working group aims for better cooperation in ASEAN on biodiversity conservation.

Most ASEAN countries have signed and ratified the major Multilateral Environmental Agreements and made attempts at aligning policies towards compliance. In addition, ASEAN has developed policies and legal responses relating to protected areas, including: Bangkok Declaration on the ASEAN Environment, 1984; Manila Declaration, 1987; Jakarta Resolution on Sustainable Development, 1987; Singapore Resolution on Environment and Development, 1992; Bandar Seri Begawan Resolution on Environment and Development, 1994; ASEAN Criteria for Marine Heritage Areas (AHP), 2002; ASEAN Agreement for the Conservation of Nature and Natural Resources, 1985 (not yet in force); ASEAN Agreement on Transboundary Haze Pollution, 2002; Hanoi Plan of Action, 1999–2004; and the Putrajaya Declaration of Regional Cooperation for the Sustainable Development Strategy of the Seas of East Asia (the PEMSEA Declaration), 2004.

There has been an increase in environmental consciousness within governments in the region, such that there are specific government ministries or agencies dedicated to environmental protection and natural resource management. These are replacing the previous system where many sectors had conflicting responsibilities for coastal and marine areas. However, there are still disputes over authority between national agencies, as well resistance from regional, state or provincial authorities if the programs clash with local interests.

#### **Brunei**

Coral reefs come under the jurisdiction of the Department of Fisheries, Ministry of Industry and Primary Resources with the inter-agency National Committee on the Environment providing some environmental coordination in association with the Shell petroleum company. Recent positive outcomes in Brunei, include a move by the Government to introduce a mandatory environmental impact assessment on major coastal projects.

#### **Cambodia**

The management of coral reef conservation is not well developed and is shared between many departments, including the Department of Fisheries of the Ministry of Agriculture, Forestry and Fisheries, and provincial governments and district governments. The Ministry of Environment



## KOMODO NATIONAL PARK FINANCING AND MANAGEMENT: CONCESSIONS FOR ECO-TOURISM

The funding provided through the Government of Indonesia for Komodo National Park is insufficient for the needs of management. The revenues collected in the Park are not returned for management, which reduces the incentives to increase the infrastructure to attract more eco-tourists. The Ministry of Finance selected the Park as a pilot site for new MPA financing mechanisms and privatisation of tourism management. The strategy to sustain Park operations suggested by The Nature Conservancy (TNC) is to develop eco-tourism, and use some of the revenue to finance Park management. They have granted a tourism concession to a joint venture 'PT Putri Naga Komodo', with 60% of the shares held by TNC and 40% by an Indonesian tourism company, PT Jaytasha Putrindo Utama. The aim is to improve tourism infrastructure, collect tourism revenues, return revenue to Park management, and use some of the revenue for a community development fund. The Park management will assess options for gate fees to include a conservation fee and change the distribution system within the Park. Studies show that 'willingness-to-pay' is much higher than the present entrance fee of Rp 30,000 (about US\$ 4) for 3 visitor days. To help set up the tourism concession, the Global Environmental Facility and TNC provided US\$ 10 million over 7 years for start-up costs, operating expenses and carrying capacity studies for Park management. During this time, the Park will generate eco-tourism revenues of nearly US\$ 8 million for management and district, provincial and central governments. The Park is expected to be financially self-sustaining after 7 years with an operational budget of US\$ 2 million per year. The increasing revenue will be achieved through a combination of higher visitor numbers and a gradual introduction of additional fees.

The aim of the Komodo Collaborative Management Initiative (KCMCI) is to ensure long-term effective management of Komodo National Park, through a collaborative management approach. KCMCI will enhance stakeholder involvement in Park management, which is the exclusive mandate of the Komodo National Park authority (Balai Taman Nasional Komodo) at the moment. All important stakeholders will be involved, including the Park authority, local government, the Joint Venture PT Putri Naga Komodo, local communities, other government agencies and private sector organizations. A very important milestone was achieved in June 2004, when the Nature Tourism Enterprise License (IPPA) was signed by the Legal Bureau of the Forestry Ministry, which will enable the venture company, PT Putri Naga Komodo, to operate. From: Peter Mous, The Nature Conservancy, Bali Indonesia, pmous@TNC.ORG.

manages protected areas including coral reefs, seagrasses and mangroves. This creates overlap, moreover there are no effective laws to protect coral reefs, although fisheries laws do include protection of marine living resources. Fisheries staff members are tasked with enforcement, and protecting critical fisheries habitats such as mangroves, seagrasses and coral reefs. Coral harvesting was an important threat until 1997, but controls have tightened and corals have been confiscated from vendors.

## TUN SAKARAN MARINE PARK, MALAYSIA

About 120 years ago, early explorers described *Semporna*, meaning a place of rest, as the most romantic place in Sabah. "Here turquoise blue seas are dotted with innumerable fantastic-shaped islands, spotted with verdure, and fringed with white sandy beaches, and coral reefs bearing Pearls, Pearlshells, Beche-de-Mer, and other valuable sea products are seen lying fathoms deep in its pellucid waters."

About 25 years ago, *Semporna* and the coral reefs were surveyed by marine biologists and described in similar way: "All the islands have considerable scenic appeal, and much to offer the visitor. The central islands are particularly dramatic, and also have an interesting flora and fauna. Surrounding waters are clear and the development of coral reefs extensive. The quality of the reefs, richness and diversity of marine life and variety of underwater habitats are superior to other areas around the coast of Sabah, and probably to Malaysia as a whole." They recommended that 8 islands, with Pulau Bodgaya and Pulau Boheydulong at the centre, be designated as the Semporna Marine Park.

In 1998, Sabah Parks, the Marine Conservation Society, WWF Malaysia, local government agencies, and island communities formed the Semporna Islands Project (SIP) to develop a plan to conserve the resources and provide for the people who depend on them. They formed a Local Community Forum of community workers and educational experts as well as scientists and environmentalists, using funds from the European Community. During the first phase (1998-2001) they assessed the status of the islands, reefs and resources, and the threats and problems. The site contained unique geology, high biodiversity, valuable natural products and stunning scenery on land and underwater. The surveys highlighted the threats to the attributes of the area, with special concern about the level of over-harvesting, and reef damage from fish bombing.

The Tun Sakaran Marine Park was gazetted in July 2004 as a 'biodiversity hotspot' and one of the most important sites for nature conservation in Sabah. The earlier attempts were unsuccessful, mainly due to fears about a loss of land and fishing rights by the local communities. The Park set a precedent because it is a mix of State Land, plus land with Native Titles and land claimed under Customary Rights. Special provisions were made in the Declaration to guarantee the rights and privileges of local people, assuring them that privately-owned land would not be acquired by the Government, and ensuring that owners of land and customary rights would be involved in all development proposals.

The most exciting challenge is that this is the first MPA in Malaysia to be zoned for multiple-use, with zones created to separate potentially conflicting activities and ensure that the conservation objectives are met. The zone boundaries are based on an understanding of the ecology, conservation and human needs, and the opportunities and threats of the different activities. They include a pelagic use/buffer zone, general use zones (e.g. for recreation and licensed, sustainable fishing), and no-take zones (to promote recovery of natural resources and maintenance of biodiversity). The main goal of the Tun Sakaran Marine Park is to ensure that the beauty, diversity, and bounty of coral reefs seen a

hundred years ago, remain for centuries. From: Elizabeth Wood, Marine Conservation Society, UK, e-wood@globalnet.co.uk); and Annadel Cabanban, Borneo Marine Research Institute, Universiti Malaysia Sabah, Malaysia, annadelc@ums.edu.my.

**TUN SAKARAN MARINE PARK**

Physical Features

Geographical location	South-east coast of Sabah, near Darvel Bay, between 4°33'N to 4°42'N, and 118°37'E to 118°51'E. The closest island is Sebangkat (10km from Semporna); the furthest is Mantabuan (25km away).
Size	Total area 35,000 ha, with 954 ha of land (8 islands) surrounded by 34,046 ha of sea and coral reefs.
Geomorphology	The central islands (Bodgaya, Boheydulang, Tetagan) are the rim of an extinct volcano, inundated by the sea. The outer islands are low limestone platforms or sand cays.
Islands: physical features	The largest island is Bodgaya (795 ha; about 8 km long and 1.5 km wide) has 3 peaks between 455 m and 360 m high. Boheydulang is 313 ha and its highest peak is 353 m. The other islands (Tetagan, Sebangkat, Selakan, Maiga, Sibuan, Mantabuan) are less than 50 ha and no higher than 80 m. Mantabuan is the smallest (10 ha), with an elevation of 1-2m.
Reefs: physical features	The length of the reef front is more than 100 km, with one section 31 km long surrounding Sebangkat and Selakan, and enclosing an extensive shallow reef. Fringing coral reefs surround each island, and there are 2 patch reefs; Church Reef and Kapikan, and the bank reef of Mantabuan. A ribbon reef and submerged reefs exists in the Bodgaya-Boheydulang lagoon.
Water depth	The Park is on the edge of the Borneo Island Shelf; average water depth is 50 m off the western edge and 130 – 145 m off the eastern edge. The reefs extend to 20 m in the west (e.g. Sebangkat) and 50 m in the east (e.g. Kapikan).

**Indonesia**

The Office of the State Minister for the Environment has overseeing responsibility for environmental concerns, while the Directorate General for Forest Protection & Nature Conservation, the Ministry of Environment, the Ministry of Forestry and the Ministry of Marine Affairs are all linked to marine and coral reef management. Indonesia is implementing a Decentralized Environmental and Natural Resources Management Program, to devolve responsibility to regional and local government bodies for the protection of the environment and natural resources.

**Malaysia**

Restructuring of various ministries within the Malaysian government following the 2004 general election, has resulted in the formation of the newly created Ministry of Natural Resources and Environment (2004). This is the overall authority for environmental management in the

## ACHIEVING SUSTAINABILITY IN MPA MANAGEMENT AFTER THE FUNDING STOPS: MABINI-ANILAO, PHILIPPINES

Implementing a 'Pay Before You Play' scheme with scuba divers solved the problem of achieving sustainability in the management of the 57,319 ha Mabini MPA. The Mabini local government in Batangas province, near Manila, Philippines charges divers who come from all over the world to view the beauty and high biodiversity of the reefs a modest fee of US\$1 per day (locals pay the same rate and there is a cheaper annual pass), with 85% of this money being used for the conservation and monitoring of the area.

Mabini was not always an attractive dive site. The reefs had been scarred by heavy pressure from a growing population and by illegal destructive fishing methods, such as bomb and cyanide fishing. The local authorities and WWF combined in 1998 to conserve the vital marine resources and prevent further loss of coral cover. Their efforts stopped destructive fishing methods, and resulted in a significant reduction in illegal fishing. The reefs have largely recovered, and now there are 319 coral species, 262 fish species and more sightings of turtles, whales and dolphins. The bay waters are key migratory pathways for economically important tuna populations, and they are also a major fishing ground with 8,000 registered fishers around the bay. Although fishing intensity has not changed, the fish catch rates are higher using the traditional methods of nets and traps.

When the contributions from the major donor funds were ending in 2003, the Mabini municipality and WWF, along with divers, resort owners, boat operators, NGOs, fishers, and scientists established a dive tourist fund to support operations of the Bantay Dagat (Bay-Watch) in protecting corals and other marine resources in Mabini. Funds were particularly used for patrols, scientific monitoring and enforcement by providing patrol boats to catch the law-breakers. Thus the frequent problem of non-sustainability following withdrawal of government aid or private foundation donor funds was avoided. This funding issue is common in projects that have achieved the conservation goals. The park managers recognised that diving is a rapid growing industry with 600,000 new divers joining the 9 million registered scuba divers in the world each year. These divers look for the 'best' sites and are prepared to pay significant sums to protect marine habitats – as long as the money goes directly to reef protection.

Joey Fullon, the 'Planet Dive' operator on Mabini says "As a diver, I pay because I can tell my kids that if we had not started paying for the corals, there would be no coral reefs worth diving on." From: Ed Tongson, WWF Philippines; [etongson@wwf.org.ph](mailto:etongson@wwf.org.ph)

country, while the management and conservation of coral reefs still falls under the Department of Fisheries in Peninsular Malaysia, and Sarawak and Sabah Parks and Department of Fisheries, Sabah. Various laws and regulations contribute to the management of marine resources.

**Myanmar**

The National Commission on Environmental Affairs handles environmental protection under the environmental policy document, the 'Myanmar Agenda 21', prepared for the Rio Summit of 1992. No framework for environmental laws exists, even though there is legislation relating to forestry and wildlife conservation. Coral reef management is under the jurisdiction of the Department of Forestry.

**Philippines**

Two government agencies (Environment and Fisheries) have the mandate to establish MPAs or fishery refuges. This leads to some jurisdictional issues. Coral reef management has been strengthened through a National Marine Policy aimed at developing a comprehensive program to manage coastal and marine resources in compliance with the United Nations Convention on the Law of the Sea. This requires that at least 15% of the coastal area in each municipality has to be declared as a fish sanctuary. A National Coral Reef Strategy is being prepared to provide an integrated management framework for the protection, conservation and rehabilitation of all coral reefs.

**Singapore**

Environmental management is under the jurisdiction of the National Environment Agency under the Ministry of the Environment and Water Resources. Recent progress has been made via the formation of Action Program Committees on Conserving Nature led by the National Parks Board to achieve the objectives of the Singapore Green Plan. This is a blueprint for environmental sustainability including programs to conserve coral reefs.

**Thailand**

There are laws and regulations that apply to all coral reefs, and additional measures for MPAs. Central agencies, provincial governments and the private sector have attempted coral reef conservation through restoration, preventive measures and education. Jurisdiction over marine resources is unclear and there have been conflicts with fisheries regulations, with the emphasis of marine park management being to support tourism, rather than protect resources or enforce regulations. The Department of Marine and Coastal Resources, Department of Fisheries and Marine National Park Authorities have laws to protect coral reefs; however, enforcement is weak, due to confusion and unclear understanding of the regulations.

**Vietnam**

Environmental protection is under the new Ministry of Natural Resources and Environment, assisted by the Vietnam Environment Protection Agency. Coral reef protection, however, is under the Department of Fisheries, which only recently has been provided with effective laws that include a comprehensive basis for marine resource management. They are tasked with developing a MPA network to include existing protected areas on the coast and islands.

**GAPS IN MONITORING AND CONSERVATION CAPACITY**

Despite a long history in coral reef monitoring in SEA, gaps still remain to be addressed. There are initiatives under way to coordinate monitoring activities and information within the region, including collating information on past and present monitoring programs, archiving summary level information, establishing a database of organisations involved in coral reef monitoring and management, and developing plans for a coral reef monitoring network to focus regional activities.

## SUSTAINING CORAL BIODIVERSITY IN MPAS: CASE STUDIES FROM INDONESIA AND VIETNAM

Bunaken National Park (N Sulawesi, Indonesia) is within the 'coral triangle', the centre of the world's tropical marine biodiversity, and Nha Trang Bay (formerly Hon Mun) Marine Protected Area (Khanh Hoa, Vietnam) is adjacent to the centre. Both MPAs encompass a group of islands just offshore from a major city (Manado in Indonesia and Nha Trang in Vietnam), and are subject to a number of mainland influences, including river run-off. The parks host rapidly developing national and international tourism operations, but importantly support significant local communities that are reliant on natural goods and services. The tourists now provide an increasing share of the operating costs, but can threaten the park's natural attractions unless well managed.

Both parks are considered 'flagship' MPAs and successful models for future implementation in the expanding global MPA network. They have adopted a co-management approach, with regular consultation and involvement of local villagers in decision-making via village MPA committees. Regular surveillance patrols enforce regulations in these MPAs, but both are subject to illegal fishing and poaching which are seriously reducing target fish stocks and overall diversity in Nha Trang Bay MPA. The MPA Authorities, local villagers and dive operators are working together to control destructive fishing and crown-of-thorns starfish (COTS) outbreaks, which are damaging the corals.

The initial phase of international support to implement these MPAs, primarily from US-AID Natural Resources Management Project III (Bunaken) and IUCN, World Bank and DANIDA (Nha Trang Bay), will cease in 2004-05. Thus it is timely to review progress towards sustaining a key biodiversity component, the reef-building corals. Like many parks, both were established without detailed assessment of biodiversity. The planning of boundaries and initial zones was based mostly on pragmatic socio-economic grounds even though both areas were recognised as having diverse reefs. Yet little was actually known of their particular biodiversity attributes, or whether the initial zoning schemes would be effective in conserving biodiversity.

Both parks are highly diverse, and host more than half of all Indo-Pacific reef-building coral species, including some which are globally rare. The richest locations are spectacularly diverse, supporting more than 190 coral species in less than 1 ha. These attributes strongly supported the selection as MPAs. Coral community analysis indicated, however, that the most diverse community type was not represented well in protected zones of either park. The management boards of the MPAs immediately set to work rectifying this situation based on detailed recommendations supported by good science, and all coral communities are now well-represented following an effective participatory process.

In Bunaken NP, coral cover, diversity and other indicators of ecological status demonstrate that present management initiatives are proving effective. The Bunaken reefs lie in the path of strong ocean currents that facilitate larval dispersal and enhance connectivity locally and among other coral populations in the region (a strong 'source and sink' function). The



currents are also important in alleviating heat stress and minimizing bleaching-related mortality, particularly during the recent major events. The selection of Bunaken NP as a flagship MPA in Indonesia and the developing MPA network for the region is well justified, especially given the increasing concern about global warming. The park provides a useful model for existing and planned MPAs, although its natural attributes place it at the higher end of the scale for resistance and resilience to disturbance; much higher than other parks.

In Nha Trang Bay, coral cover was much reduced by a combination of recent impacts. Despite the high overall diversity, local population sizes of many reef species are small in comparison with Bunaken NP, which is larger in area (approx. 7 times), and has stronger current flows that enhance connectivity. Consequently, reef communities in Nha Trang Bay may have lower resistance and resilience to disturbance, and more concerted management efforts may be required to rebuild ecosystem integrity. Issues of scale may prove to be very important, and a strong case can be made for expanding Nha Trang Bay MPA to include more reef habitat, thereby increasing local population sizes for corals, fish and other reef species in protected zones. However this will require more political will, management capacity, and stakeholder agreement. Importantly, Nha Trang Bay is the first in Vietnam's planned network of MPAs, and management capacity is thus expanding rapidly from a low base. Hence the park also provides a useful model for developing a regional network.

Significant national and local management capacity has been developed in both MPAs, however it remains to be seen whether this is sufficient to manage the parks effectively, while also contributing to the development of the larger network. The MPAs have demonstrated management flexibility, host significant tourism that contributes to sustainable financing, and also have a strong co-management focus. Yet both face enormous challenges in controlling threats such as inappropriate development and illegal fishing. Increased responsibility and 'ownership' by the local communities will be essential if the joint objectives of ecosystem protection and socio-economic development are to be achieved. Provincial and national governments, particularly in relation to fisheries and Integrated Coastal Management, can foster this through continued support.

Ongoing monitoring of the ecology of these MPAs is crucial to supporting management, and involving international donors. The coral reef science and conservation community is invited to offer continued assistance and guidance, if requested by the MPA managers. From: Lyndon DeVantier, Emre Turak, Glenn De'ath, Vo Si Tuan, Bernard O'Callaghan, Chu Tien Vinh, Mark Erdmann, Reinhart Paat; contact [l.devantier@aims.gov.au](mailto:l.devantier@aims.gov.au)



## MPA RATING AND DATABASE TO IMPROVE CORAL REEF CONSERVATION IN THE PHILIPPINES

The Philippines developed a national coastal resource management framework for sustainable use and conservation of the coastal and marine environment. The establishment of MPAs is one of the most effective strategies for biodiversity conservation and fisheries management. Since the 1970s, more than 600 MPAs have been legally established in the Philippines, however, fewer than 20% of these are fully enforced, and very few protect habitats or fisheries.

The Marine Protected Coast, Reef and Management Database (MPA Database) was developed by the Coastal Conservation and Education Foundation, Inc. (CCE Foundation) in 2001 to provide information on the effectiveness of MPAs in the Philippines. The MPA Database is a basic framework to monitor and evaluate MPA effectiveness against a minimum set of criteria on the success of management programs and public compliance. There is management rating to guide managers in implementation to increase the potential of MPA success. The system encourages regular ecological and socio-economic monitoring to measure actual success of the MPA and presents the data for easy access. The MPA Database has increased awareness and improved understanding on the functions and benefits of MPAs; focussing on 60 MPAs in 20 municipalities in the provinces of Cebu, Negros, Oriental, Bohol, Siquijor, Batangas, and Palawan, with collaboration with 7 national government agencies, 10 NGOs, 4 academic institutions and 5 coastal resource management projects. These partners added information on 200 more MPAs in 11 provinces. The MPA Database System is being expanded and provided to all user groups to improve education, adaptive management, policy recommendations and MPA management nationwide.

The MPA Database surveyed half of the 600 MPAs in the Philippines, with the majority (91%) being small community-based managed MPAs declared under the Local Government Code of 1991 that decentralizes the authority to manage municipal waters to local governments. About 9% are large parks declared by Protected Area Wildlife Bureau of the Department of Environment and Natural Resources within the National Integrated Protected Areas System Act in 1992. A major reason why many of the MPAs failed after establishment was that management groups did not know how to move to the next phase of management. The MPA Database will allow managers to evaluate their progress and identify weaknesses in implementation. The majority (57.5%) of 212 MPAs are still in levels 1 and 2; 33% are at level 3 with evidence of good enforcement; and very few (9%) are at levels 4 and 5. Many MPAs have difficulties in sustaining management efforts due to the lack of technical support, insufficient budget, and weak law enforcement. From: Alan White, Anna Blesilda Meneses, Melody Ovenden. The Marine Protected Area Project, Coastal Conservation and Education Foundation, Cebu City, The Philippines

Result of the management rating system for 212 MPAs in the MPA Database.

Rating Level	MPA Records #	%	Management Performance	Implications
Level 1	29	13.7%	Passing	MPA is in initiated phase; establishment activities have begun.
Level 2	93	43.9%	Fair	MPA is in established phase; the MPA is legalized and management activities have started.
Level 3	71	33.5%	Good	MPA is in enforced phase; MPA regulations are implemented and management activities maintained for 2 years or more.
Level 4	14	6.6%	Very good	MPA is in sustained phase; MPA is well enforced over the years; participation and support from the LGU and community is consistent.
Level 5	5	2.4%	Excellent	MPA is in institutionalised phase; management and enforcement is consistently maintained and assured by additional legal support.

Summary of coral reef surveys for 66 MPAs in 8 different provinces, with the emphasis on the health of corals.

Province	No. of MPAs with coral data	Area covered (ha)	Status of coral cover*							
			Poor		Fair		Good		Excellent	
			# of MPA	Area (ha)	# of MPA	Area (ha)	# of MPA	Area (ha)	# of MPA	Area (ha)
Palawan	1	33,200			1	33,200				
Batangas	5	37			2	12	3	25		
Bohol	18	315	8	225	4	50	6	40		
Cebu	18	317			6	143	9	144	1	10
Negros Oriental	10	187	1	6	5	76	4	105		
Siquijor	9	112	5	56	1	27	3	29		
Davao del Sur	2	70	1	20	1	50				
Sarangani	3	35					2	25	1	10
Total	66	34,273	15	307	20	33,558	27	368	2	20

\* Poor – 0-25% coral cover; Fair – 26-50% coral cover; Good – 51-75% coral cover; Excellent – 76-100% coral cover

Initial information has highlighted key areas for immediate action to maintain coral reef management and conservation as a top priority. There is a critical lack of coral reef data storage facilities and data management systems in countries, as well as the region. Some countries, like Philippines and Indonesia, have well established data management facilities, making these the exception. Reporting on the regional coral reef status this time was difficult, and contradictory information was often presented because the data were not organised. Thus, a recommendation will be to form a regional network to strengthen the data management capacity of the countries. An initial attempt has been made, but more resources are needed to achieve this within the next two years.

*An assessment of the current capacity and future needs for coral reef monitoring in SEA showed that there were requirements for more monitoring, especially of fishes and socio-economic parameters, as well as considerable capacity building across virtually all countries.*

	Brun	Camb	Indo	Mala	Myan	Phil	Sing	Thai	Viet
CR Monitoring Sites & Methods Needs									
No of Monitoring Sites	+	0	+	+	+	+	0	0	+
Spread of Sites	0	0	+	+	+	0	0	0	0
Variety of Methods	+	+	0	0	+	0	+	0	0
Required Monitoring	Fish, S-E, P-C	Fish, S-E, P-C	Fish, S-E, P-C	Fish, S-E, P-C	Fish, Algae, Inverts, S-E, P-C	P-C	Fish, Algae, P-C	Fish, S-E, P-C	Fish, S-E, P-C
CR Monitoring Expertise & Training Needs									
Benthos Surveys: "High-level"									
Expertise	+	+	+	+	+	N	+	+	+
Training	+	+	+	+	+	N	N	+	+
Benthos Surveys: "Entry-level"									
Expertise	+	+	+	+	+	N	N	+	+
Training	+	+	+	+	+	N	N	+	+
Fish Surveys: "High-level"									
Expertise	+	+	+	+	+	N	+	+	+
Training	+	+	+	+	+	N	+	+	+
S-E Surveys: "High-level"									
Expertise	+	+	+	+	+	N	NA	+	+
Training	+	+	+	+	+	N	NA	+	+
Coral ID: "High-level"									
Expertise	+	+	+	+	+	N	N	N	+
Training	+	+	+	+	+	N	+	N	+
CR Monitoring Infrastructure & Funding Needs									
Dive equipment	N	+	+	+	+	N	N	N	+
Operational Costs (fuel, tank fills, etc)	+	+	+	+	+	+	+	+	+
Local Funding	+	+	+	+	+	+	+	+	+
International Funding	N	+	+	+	+	+	N	+	+

+ = An increase needed; 0 = Sufficient Monitoring; N = Not Necessary; NA = Not Applicable; S-E = Socio-Economic; P-C=Physico-Chemical; Brun=Brunei; Camb=Cambodia; Indo=Indonesia; Mala=Malaysia; Myan=Myanmar; Phil=Philippines; Sing=Singapore; Thai=Thailand; Viet=Vietnam

## NATIONAL POLICIES AND CORAL REEF MANAGEMENT IN THAILAND

A National Coral Reef Strategy: The Thai cabinet adopted the Policies and Action Plan in 1992. However, this failed to reverse coral reef degradation because it was not functional at the local level. The National Coral Reef Strategy: Policies and Action Plan is under revision, with new directions being mapped over 5 years, based on the national meeting held in January 2004. Ninety-eight projects were identified under 6 policy actions, with specific action measures. From: Thamasak Yeemin, Marine Biodiversity Research Group, Ramkhamhaeng University Huamark, Bangkok, Thailand, thamasakyeemin@yahoo.com

Policy	Measures	No. Projects
1) Manage coral reefs according to different ecological and economic values to maintain a balance of uses	1) Improve coral reef classification	3
	2) Determine criteria and measure for each management category	2
	1) Successful implementation of methods to prevent coral reef degradation from the pilot study sites to other areas	6
2) Reduce reef degradation by increasing the effectiveness of existing laws management plan and application of appropriate technology	2) Prevent impacts from new coastal developments	7
	3) Reef 'code of conduct'	3
	4) Expand local extension programs in fisheries habitat conservation	7
	5) Enforce more effectively existing laws against illegal activities	4
	6) Strengthen the capacity of local government in site planning and management	2
	1) Launch national and local public information campaigns	7
3) Build and maintain strong and broad public support	2) Encourage volunteer groups, user and public participation in reef management	11
	3) Coral reef curriculum in schools and colleges	6
4) Revise Royal Thai Government legal, regulatory, and institutional framework	1) Amend law and regulation concerning coral reef management	3
	2) Improve coral reef management processes	2
	3) Provide interagency leadership and coordination	6
	4) Develop marine national park system plan	4
5) Monitor and evaluate progress	1) National monitoring program	7
	1) Basic coral reef research program	9
6) Support management through scientific research and innovation	2) Applied coral reef research program	5
	3) Promote and develop researchers in the fields of reef and marine ecology	3

A needs assessment for SEA showed that the number of monitoring sites were sufficient for some countries, although some adjustments of sites may be required for better geographical analysis. The distinction between the terms *areas*, *sites*, *stations* and *transects* needs to be standardised, to facilitate comparisons between countries and to remove the biases in this report. For example, more sites are monitored in MPAs, or close to research stations and near tourism resorts, while remote sites are rarely visited.

Another area requiring attention is the standardization of monitoring methods, where possible, to minimise the increasing diversity, especially those used to monitor corals and other benthos. This assessment shows that several parameters (like % coral cover) are consistently monitored, whereas fishes and indicators to assess coral bleaching, diseases, invasive species and plague outbreaks, sea surface temperatures and socio-economic indicators are rarely included.

All countries reported a critical lack of coral reef monitoring expertise (but less so in the Philippines) to make meaningful assessments; therefore capacity building needs to be increased as a matter of urgency. In some of the less developed countries like Cambodia, Myanmar and Vietnam, there is insufficient infrastructure, basic equipment and funding for effective monitoring.

#### **RECOMMENDATIONS TO IMPROVE CORAL REEF CONSERVATION AND MANAGEMENT**

The conservation and management of coral reefs is a priority issue in many SEA countries, and efforts are being made to enhance activities, programs and legislation to ensure better management of the resources. Despite an increased awareness and the implementation of proactive measures, more needs to be done at a regional level to integrate information and efforts. To this end, the following recommendations are proposed:

- Increase monitoring efforts and initiate integrated capacity building programs, which should include MPA management options. Ongoing monitoring programs are still insufficient and under-represented in some countries;
- Establish better coordination and cooperation within regions. SEA countries need to work more closely, exchange lessons learned and establish more joint-programs;
- Work towards better MPA effectiveness in coral reef protection and expand the network of MPAs. Coral reefs are not well represented in MPAs and more legislation is needed to protect coral reefs;
- Develop Reef Health Indices. Monitoring groups require robust and effective universal reef health indices to assess the status of reefs;
- Develop data management systems for coral reef information. Many countries lack data management systems, and are unable to contribute effectively to a regional database; and
- Increase public awareness and education programs. The public can have a strong influence on policy and legislation, and more efforts are needed to involve the public by keeping them better informed on coral reef issues.

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**ICRAN**

**BUNAKEN NATIONAL PARK, INDONESIA – ICRAN DEMONSTRATION SITE**

Bunaken National Park (BNP) is on the northern tip of Sulawesi and covers 890 km<sup>2</sup> of diverse reefs and large mangrove forests. The initial management problems included destructive fishing and farming practices, poorly planned coastal development and unethical business and political practices. These problems lead to mistrust amongst local stakeholders and managers, which, combined with disorganised management strategies, resulted in poor compliance with management objectives and unclear zoning regulations. In response to stakeholder demands for fair and accountable management, a representative management advisory board (effectively a co-management strategy) was developed to manage revenues generated from the new park entrance-fee system, and to coordinate patrols and conservation and development activities.

The goal of the fee system was to fully support the BNP Authority , with an annual target of US\$250,000. Now, 80% of the revenue supports conservation programs, including enforcement, education, waste management, and village development, while the remaining 20% is divided among the local, provincial, and national governments. Stakeholders also demanded that the 8 zone system be simplified to reflect the 3 primary values: conservation; tourism; and fisheries. The conservation and tourism zones are 'no-take' and include reef fish spawning aggregation sites and long-established dive sites. A joint patrol system has significantly reduced blast fishing and cyanide fishing, illegal coral mining and mangrove cutting. Higher compliance has resulted in an increase in coral cover and abundance of commercial fish species.

The key to achieving sustainable management has been a massive effort to create a single 'community' with a strong sense of awareness and ownership of the marine resources. To facilitate co-management, the management advisory board consists of government agencies, village stakeholders and representatives of the tourism sector, academia, and NGOs. Furthermore, all 22 villages are represented in the BNP Concerned Citizen's Forum, which allows villager input into management decisions as well as serving to socialise management policy to its constituents and improve communication among all interest groups. Strong private sector participation in park management has resulted in a commitment to increase employment of locals, participation in educational programs, and assistance with park enforcement.

**Ecological Monitoring:** The Bunaken National Park Office has monitored reefs for the last 5-6 years, and conducted training on coral identification, monitoring and mapping. There is a need for additional benthic, fish and spawning site monitoring.

**Socio-economic Monitoring:** There has been minimal monitoring of villager income.

**Contact:** Widodo Ramono, Department of Forestry, wsramono@eudoramail.com

**Coral reefs** are 60% of the natural resources.

**Ecological Monitoring** is occasional.

**Socio-economic Monitoring** is occasional.



**ICRAN**

**MU KOH SURIN, THAILAND –ICRAN DEMONSTRATION SITE**

Mu Koh Surin National Park is in the Andaman Sea, 50 km off of Thailand’s western coast. The Surin Islands are the southerly extension of the Mergui Archipelago and are surrounded by extensive reefs, mangroves and seagrass beds. A population of sea gypsies inhabits the islands and is responsible for much of the target species fishing. The primary resource users, however, are tourists and associated Park fees, dive fees and boat permits contribute significantly to the Park budget. The Marine National Park Division of the National Park, Wildlife and Plant Conservation Department currently manages the park.

The current management plan details the division of the park into 6 areas: mooring buoy installation and maintenance; patrolling of the marine area; enforcing fisheries regulations; temporary closure of areas for rehabilitation of the reefs; and no-commercial fishing regulation within 3 km offshore. Tourism and public education elements of the management plan include the park fees (an entrance fee and scuba diving fee), park permits for tour boats, public education and media awareness programs, and community programs. Finally, the management plan includes an economic incentive program for the Sea Gypsies. As part of the ICRAN project, Mu Koh Surin National Park, together with volunteers and universities, has developed a series of reports on: the status of coral reefs of the Surin Islands; management recommendations and indicators; student research on coral reef fish and scleractinian corals; local communities and other management issues. Researchers have completed a baseline assessment of the ecology, objectives, management activities and current legislation of the national park, and have refined future management plans. Studies on coral recruitment have helped park managers predict natural recovery and aid in reef restoration efforts. A public awareness program was developed, including the installation of permanent signs and a Thai translation of the “Coral Reef Monitoring for Management”. A database of articles and research has been developed and a geographic information system including underwater video images was completed for Mu Koh Surin.

**Ecological Monitoring:** The Phuket Marine Biological Center, Kasetsart University, and Reef Check are responsible for much of the ecological monitoring in Mu Koh Surin, with help from volunteer groups supported by the Singapore International Foundation and Ramkhamhaeng University.

**Socio-economic Monitoring:** Socio-economic evaluation of indigenous sea gypsy livelihood has been conducted, and established monitoring programs are jointly managed by Singapore International Foundation and the Park.

**Contact:** Thamasak Yeemin, Ramkhamhaeng University (thamasakyeemin@yahoo.com)

**Coral reefs are 60% of the natural resources.**

**Ecological Monitoring is effective.**

**Socio-economic Monitoring is effective.**

**ICRAN**

### **APO ISLAND, PHILIPPINES – ICRAN DEMONSTRATION SITE**

Apo Island is one of the earliest community-based marine reserves. Reef protection began informally when Silliman University initiated the Marine Conservation and Development Program in 1982. Years later, the island community and the local council formally agreed to the establishment of a marine reserve surrounding the entire fringing coral reef of the island and a smaller (0.45 km<sup>2</sup>) ‘no take’ fish sanctuary. The island is now managed by the Marine Management Committee of the Apo Island community with support from the Municipal Government and Silliman University. The community is now prospering in a sustainable way with a steady increase in the standard of living, evidenced in the growing number of houses made from cement. Studies on Apo fishery management have presented some of the first evidence that Marine Protected Areas can create a sustainable fishery: an increased catch per unit effort, maintenance of fish yields (19-25 t km<sup>2</sup> per year) for the past 2 decades, and a change in fishing patterns; drift gill-nets, used in deeper offshore water, are no longer commonly used.

As part of the ICRAN project Apo Island is paired with Ninh Thuan, Vietnam (Box p 253) to share knowledge and experiences. Site visits between key stakeholders have involved the transfer of lessons learned from Apo, specifically the importance of 1) communication amongst communities, 2) designation of a community organiser to lead, and 3) involvement of local communities in protecting their marine resources. Apo Island also hosted a “Workshop on Capacity Building in Community-Based Coastal Resources Management” focusing on the role of the community organiser, enhancement of community-based management, the role of mass communication in building public awareness, and development of sustainable tourism. Additionally, Apo Island has completed a baseline assessment of existing management schemes as well as an assessment of contamination in the coastal waters to analyse the impact of resort waste. Other activities have included a poster contest to increase public awareness, with the proceeds contributing to the communities’ alternative livelihood project, and tourism impact studies which examined coral breakage and tourist numbers and activities.

**Ecological Monitoring:** A fish monitoring program is in place. Reef Check surveys have been undertaken since 1998 and studies have been done by Silliman University.

**Socio-economic Monitoring:** A monitoring program that examines the impacts of tourism on the coral reef was planned to commence in 2003.

**Contact:** <http://mozcom.com/~admsucrm/apo.htm>

**Coral reefs are 70%** of the natural resources.

**Ecological Monitoring is effective.**

**Socio-economic Monitoring is planned.**

ICRAN

WHS

MAB

**KOMODO NATIONAL PARK, INDONESIA – ICRAN DEMONSTRATION SITE**

Komodo National Park, in the Lesser Sunda Islands of Indonesia, encompasses a number of islands, the largest of which are Komodo (34,000 ha) and Rinca (20,000 ha). While it is best known for the large endemic lizard, the Komodo dragon, the waters are very rich in marine life, supporting more than 200 hard coral species, seagrasses, mangroves, manta rays, 16 species of cetaceans, turtles, and over 1000 fish species. Nearly 113,500 ha of waters surrounding the island are under the jurisdiction of the park. Komodo National Park was established as a Biosphere Reserve by the United Nations in 1977, pronounced a National Park in 1980, and declared a World Heritage Site in 1991. A 25-year management plan was developed for the park in 1995 with the goal of obtaining a well-managed, self-sustaining park that effectively protects biodiversity, enhances fisheries and ensures sustainable use (tourism and education) of the Park resources, whilst maximising benefits to the local communities.

The park is still threatened by over-exploitation of the natural resources and destructive fishing. In an effort to reduce these threats, managers of Komodo conduct comprehensive community outreach and conservation awareness campaigns, promote sustainable livelihood activities, have a strong patrolling and enforcement program, and encourage ecotourism. Komodo also promotes public awareness through events such as Dive In To Earth Day cleanup dives and a Crown-of-thorns removal event. Park staff and dive operators have participated in a workshop coordinated and hosted by the Coral Reef Alliance on best practices for dive operators.

Komodo is focused on MPA development and helping its paired site from China (Sanya Nature Reserve) to improve management. During a manager’s workshop, Komodo prepared a rough guide to assist Sanya in assessing the sources of stress to corals. After a change in the ICRAN pairs of East Asian sites, the Koh Rong delegation from Cambodia visited the activity sites of The Nature Conservancy (TNC) in and around Komodo, such as the community-based fish growout farms, pelagic fisheries alternative livelihood, mooring buoy program, fish monitoring training, spawning aggregation site, and seaweed culture project to pass on their experiences and lessons learned.

**Ecological Monitoring:** Every 2 years TNC monitors 185 sites for corals, fish, and grouper and wrasse spawning aggregation sites.

**Socio-economic Monitoring:** TNC conducts socio-economic studies regularly and undertook a baseline assessment of existing management schemes of the ICRAN project.

**Contact:** Rili Djohani, The Nature Conservancy (rdjohani@attglobal.net)

**Coral reefs** are 40% the natural resources.

**Ecological Monitoring** is effective.

**Socio-economic Monitoring** is effective.


 WHS

### TUBBATAHA REEF NATIONAL MARINE PARK, PHILIPPINES

The Tubbataha Reef National Marine Park consists of 2 uninhabited coral atolls in the Sulu Sea, 92 miles southeast of Palawan. The coral reef biodiversity is outstanding, making the location important ecologically and a popular dive site. The park covers 33,200 ha with many species: 379 corals; 441 fish; 6 sharks; 7 seagrasses; 79 algae; and 8 cetaceans. The islets are important nesting sites for sea birds and turtles. Despite being remote, the Tubbataha reefs were damaged in the 1980s by bomb fishers from the Philippines, Taiwan and China. Although fishing was limited by the monsoons, living coral on the reef-flats decreased by 24% in 5 years. The reefs are managed by the multi-sectoral Tubbataha Protected Area Management Board under the auspices of the Palawan Council for Sustainable Development and the Department of Environment and Natural Resources. Technical assistance is provided by research institutions and NGOs, with financial support from the government, external grants, and user fees.

Long-term collaboration by the stakeholders reversed the damage from illegal fishing, anchors, and collection of marine animals. Dedicated NGOs conducted research, installed mooring buoys, built a field station, and are responsible for park management with the Philippine government. Tubbataha is the only MPA in the Philippines, which is routinely patrolled by the Philippine Navy and Coast Guard. Private tourism operators assist in law enforcement and management decision-making. This strong collaboration between government, NGOs, and the private sector is critical for the conservation of this valuable marine resource.

**Ecological Monitoring:** WWF-Philippines have conducted substantial, annual monitoring since 1997; this is now included in the annual work and financial plans of the management board.

**Socio-economic Monitoring:** The need for socio-economic monitoring and sustainable resource management on Cagayancillo Island, 120 km northeast of Tubbataha is recognised in Management Plan. Information, education and communication activities have strengthened local law enforcement and support for marine conservation initiatives. Local marine reserves and training packages have been established in partnership with the local government, which conducts socio-economic monitoring in collaboration with the Park managers and WWF.

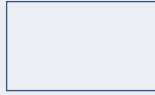
**Monitoring Effectiveness:** Baseline data from 1997 to the present contribute to management decision-making. Socio-economic monitoring has identified the community interventions needed improve the standard of living in Cagayancillo.

**Contact:** Angelique Songco, (tmo@mozcom.com).

**Coral reefs are 30% of the natural resources.**

**Ecological Monitoring is effective.**

**Socio-economic Monitoring is effective.**



**MAB**



### **PALAWAN, PHILIPPINES – MAN AND THE BIOSPHERE RESERVE**

The Palawan Biosphere Reserve includes the entire Province of Palawan, in the Philippines, covering around 14,000km<sup>2</sup> and populated by 750,000 people. Palawan has 1,700 islands and islets, and was declared as a Biosphere Reserve, one of only two in the country, by UNESCO in 1991. Within its territory is the Tubbataha Reef Marine Park which was inscribed on the World Heritage list in 1993. The province has a unique and diverse fauna and flora and is known as a 'last ecological frontier'. Palawan has some of the best developed coral reefs in the country, with fringing and patch reefs along most of the coast and live coral cover reaching between 50 - 90% in some places. However, agriculture, fishing (especially with explosives and poisons), mineral extraction and offshore oil and natural gas, as well as tourism, threaten the environment.

In 1992, a 'Strategic Environmental Plan' for Palawan was adopted and through it an 'Environmentally Critical Areas Network' is being implemented. The Environmentally Critical Areas Network is a system of management zones graded from strictly protected to development areas. The terrestrial component has a core zone, a buffer zone (divided into restricted, controlled and traditional use areas) and a multiple/manipulative use zone. The coastal/marine component also has a core and multiple use zone.

**Ecological Monitoring:** Reef Check has been conducted in Palawan since 1997 and the Marine Science Institute of the University of the Philippines has included Palawan in their occasional nation wide surveys of coral reef health.

**Socio-economic Monitoring:** Rapid Rural Assessment (RRA) of the coastal areas of in Palawan is currently ongoing.

**Coral reefs** are 30% of the natural resources.

**Ecological Monitoring** is effective.

**Socio-economic Monitoring** is effective.



## 10. STATUS OF CORAL REEFS IN EAST AND NORTH ASIA: CHINA, HONG KONG, TAIWAN, KOREA AND JAPAN

TADASHI KIMRUA, CHANG FENG DAI, SEONGHWAN PAE, HUANG HUI,  
PUT O. ANG, JONG GEEL JE AND CHOI CHOYCE L.S.

### ABSTRACT

Most corals in East and North Asia are still under the stress caused by human activities in coastal areas. Each country in this region has conducted and developed coral conservation and management programs, and the results of these programs will be seen in the effectiveness of conserving coral reefs in the future.

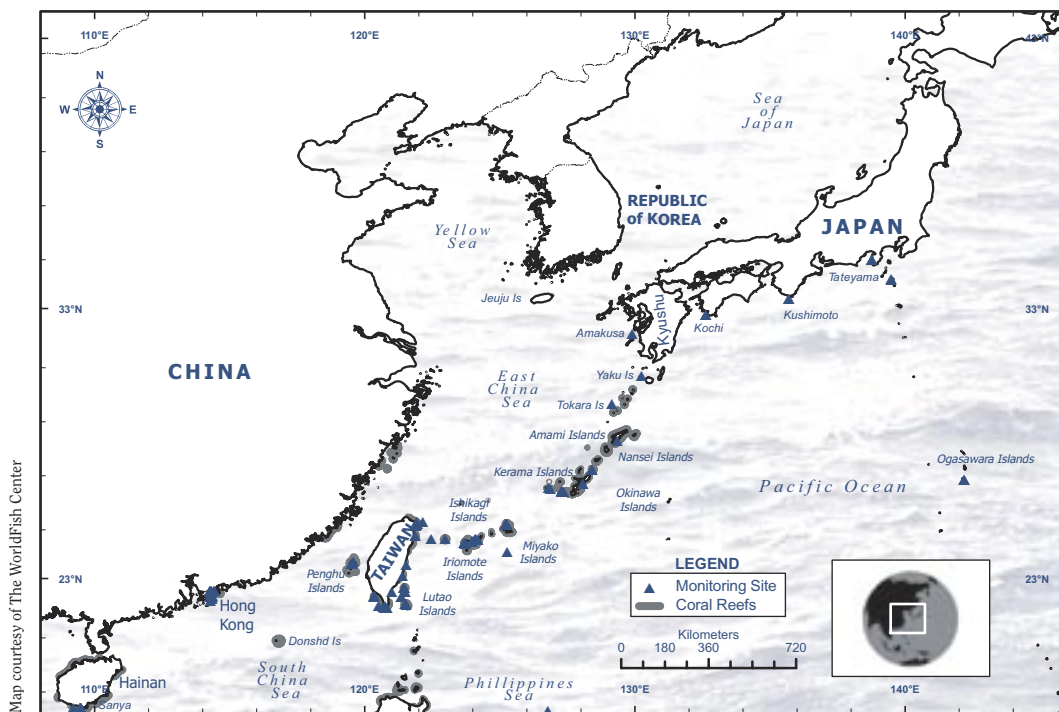
**100 Years ago:** The coral reefs were predominantly healthy with high coral cover and minimal stress caused by human activities. There was considerable boat traffic around harbours.

**In 1994:** The reefs were threatened by natural coral predators (crown-of-thorns starfish COTS, *Drupella*) and human disturbances (destructive fishing practices, marine pollution). There was heavy coastal pollution near the large cities and coastal towns.

**In 2004:** Degradation of coral reefs continues under the influence of increasing human pressures on the ecosystems. Natural disturbances occurred more frequently, probably caused by increasing rates of climate change. All the countries in this region have or are planning coral reef monitoring programs, management programs and the development of MPAs to reduce the current rate of coral degradation. There is a growing sense of regional cooperation for coral reefs.

**Predictions for 2014:** More MPAs and management will be implemented. All the countries can share both successful and unsuccessful practices to learn more effective management of coral reefs. There will be more MPAs declared and improved coral reef management will be implemented. The countries will be sharing the lessons from successful and unsuccessful practices to learn more effective management of coral reefs. These management actions will mean that some coral reefs will remain healthy, whereas the bulk of the reefs in the region will continue to decline under a combination of growing human pressures and the increasing rate of global climate change.





## INTRODUCTION

This region, including mainland China, Hong Kong, Taiwan, Korea and Japan, is at the northern edge of coral distribution in East Asia. **China** has an extensive coastline from Vietnam along the northern South China Sea to the Korean peninsula in the Bohai Sea. The mainland of China is not influenced by the warm Kuroshio current. This lack of warm water limits the growth of corals and the development of coral reefs along much of the mainland Chinese coast. Typical fringing reefs, however, occur around Hainan Island – a truly tropical island – but only limited and scattered subtidal coral communities, or fringing reefs, occur along the west coast of Leizhou Peninsular of Guangdong Province in the south to Dongshan Bay (23°45'N) of Fujian Province in the southeast. Coral communities can be found also along offshore islands from Diaoyudao Islands (25°45'N) to the north of Taiwan, to Weizhou Island in Guangxi along the southern coast. Coral reefs are not well developed around **Hong Kong**, but there are coral communities on the northeast and eastern shores, and patchy distribution of coral colonies in the southern and southwestern coasts.

In **Korea**, corals are restricted to a few areas influenced by the warm Kuroshio Current, with Jeju being the best habitat for corals. Here, some distinct soft corals with tropical and subtropical fauna are found – largely due to the influence of a branch of the Kuroshio Current. There are 127 coral-like species in Korea with 97 species growing in Jeju. This includes 65 coral species that are found nowhere else in Korea. There are also soft corals around three islets, Munseom, Bumseom and Supseom in the southern area between 10 and 40 m depth.

The seas around **Japan** range from sub-tropical to sub-arctic conditions, with hard corals distributed from the Southern Ryukyus, northward to Tokyo Bay along the east mainland

Pacific coast and to Sado Island in the Sea of Japan. The major coral reefs consist of North Ryukyus (the Tokara Archipelago), Middle Ryukyus (the Okinawa and Amami islands) and South Ryukyus (the Miyako and Yaeyama islands), and around Ogasawara Islands. The Northern Ryukyus form the boundary between coral reefs and rocky reefs on the Pacific coast, and further north there are predominantly coral communities from Kagoshima Prefecture to Chiba Prefecture on the mainland. Manazuru in Sagami Bay and Tateyama in Tokyo Bay have the highest latitude coral communities at 35°N. In the Sea of Japan, the highest latitude coral reef is at 33°N at Iki Island in Nagasaki Prefecture, however, hard corals occur as far as Sado Island (38°N) in Niigata Prefecture.

Coral reefs occur in all waters around **Taiwan** except on the sandy west coast areas. The best-developed fringing reefs are around the southern tip of the island – the Hengchun Peninsula. These reefs have diverse and abundant hard and soft corals. There are patchy coral communities elsewhere around the island, with a dominance of hard corals. Rich coral reefs occur around the offshore islands of Lutaο (Green Island), Lanyu (Orchid Island) off southeast Taiwan, Hsiaoliuchiu and Penghu Islands (the Pescadores) to the southwest, and the Penghu Archipelago 50 km west off Taiwan in the Taiwan Strait.

True and well-developed reef systems are found in the South China Sea. There are about 128 atolls in the South China Sea, including the islands of Dongsha, Xisha, Zhongsha and Nansha, of which about half are emerged atolls, and another half are drowned atolls. Dongsha (Pratas) Island and Taiping (Itu Aba) Island in the South China Sea are flourishing atolls. However, coral cover on Dongsha Island has declined, following intensive overfishing and coral bleaching, to less than 10% (Box p 294).

## STATUS OF CORAL REEFS

### China

Before 1984, coral reefs in China were in good condition, with coral cover often more than 70% e.g. cover was 76% in Daya Bay, Guangdong province in 1984. Prior to that, cover was more than 70% in Luhuitou, Sanya, Hainan province in 1960s; similarly it was above 70% in Yongxing Island, Xisha Island in the 1970s. There was a decline in coral reef status in the 1990s, in parallel with rapid social-economic growth. Coral cover dropped to 32% in Daya Bay in 1991, and was 38% in Luhuitou, Sanya, in 1994. Surveys in 2002 reported coral cover at 35% in Daya Bay and 19% in Luhuitou, whereas it was higher (68%) in Yongxing Island, and Xisha Island.

### Hong Kong

The coral communities vary considerably, but some have high coral cover. In the 1980s, there was 51-81% cover in northeast Hong Kong, with 36 coral species reported, however, these reefs have come under heavy fishing pressure, including the use of destructive fishing methods. Heavy pollution in Tolo Harbour and Tolo Channel in 1994 corresponded with a decline of coral cover and diversity. Four marine parks and one marine reserve have been designated and of these, Tung Ping Chau and Hoi Ha Wan Marine Parks were primarily designated to protect coral communities. Coral cover on these marine parks ranges from 17% to 71%; and at least 84 species of corals have been reported from Hong Kong. Coral communities in the marine parks are closely monitored. There were also 33 teams of volunteers involved in Reef Check 2004, making general surveys on 33 sites around Hong Kong. Many of these Reef Check sites are outside the marine parks.

## Korea

Coral monitoring, especially biodiversity surveys has been conducted at Jeju Island since 1998. Uncontrolled collection and fishing have resulted in decreases of coral cover and fish abundance at the biodiversity rich areas of Munseom, Supseom and Bumseom. The biodiversity surveys identified 318 benthic species including 138 mollusc species, 83 crustaceans, 38 polychaetes, 21 echinoderms and 9 sponges. A series of biodiversity baseline studies were conducted to assist in the conservation of coastal and marine habitats with high biodiversity on the coast and adjacent seas of Jeju. The bottom communities could be divided in 3 vertical patterns: oyster reefs with high biodiversity; shallow communities; and deep habitats below 10 m depth.

## Japan

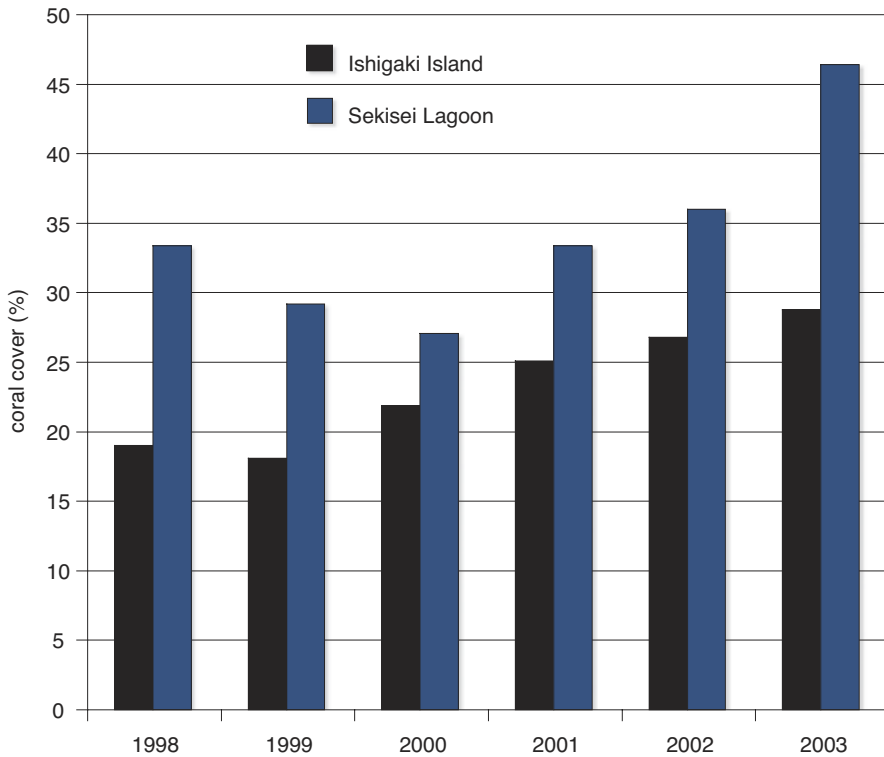
The average coral cover at 123 stations in Sekisei lagoon in 2003 was 46.3%, an increase of 10.4% since 2002. The average coral cover at 75 stations around Ishigaki Island was 28.7%; only a 2.0% increase on the 2002 averages. These data show a trend of increasing coral cover in the Southern Ryukyus, after the bleaching losses in 1998.

Monitoring at 5 sites further north (Kerama Islands, Okinawa Island, Amakusa, Ashizuri and Kushimoto) showed healthy coral communities, except for Okinawa Island where there was severe coral damage from bleaching in 1998. The average coral cover in 2003 was: 30.9% in Kerama Islands at 10 stations; 8.5% at 17 stations in Okinawa Islands; 30.8% in Amakusa at 12 stations; 28.2% in Ashizuri, at 11 stations; and 48.9% in Kushimoto at 14 sites. Corals in Okinawa have not recovered from the 1998 bleaching damage, however, there are many juvenile colonies – indicating a constant supply of new recruits from source reefs. A tropical coral species, *Leptoseris papyracea*, was recently observed in the West Coast of Shikoku and large coral communities of *Acropora hyacinthus*, covering 50% of the bottom, were found much further north of the former distribution in the Kii Peninsula.

## Taiwan

Coral reefs at 32 sites in 8 regions have been monitored by the Taiwanese Coral Reef Society and other volunteers, using Reef Check methods from 1997 to 2004. Hard coral cover at these 32 sites showed wide variability, with the highest cover at the Inner Bay of Chinwan (65%), Penghu Island, Hsiangjiaowan (64%) in southern Taiwan, and Kunguan (59%) at Lutao. However, coral cover at 18 of the 32 sites was lower than 30%, indicating that these reefs were under severe stress or had been heavily damaged. Coral cover on the northeast coast and Ilan County was generally below 30%, indicating a marginal environment for coral growth. However, coral cover at 4 of 6 sites in more favourable tropical environments in the south was lower than 30%. These results show a general trend of declining coral cover on Taiwanese coral reefs. There were however, several sites with encouraging recovery after the 1998 coral bleaching. The average trend was of little change in coral cover from 1997 to 2004; this analysis includes reefs with increasing as well as decreasing coral cover.

Hard corals dominate the bottom at most sites, although soft corals were relatively abundant at 4 sites, and there was a dominance of coral skeletons covered by macroalgae at Dongsha Island, which reflects severe reef damage (Box p 294). Destructive fishing and rising sea surface temperatures have damaged reefs at other sites in southern and eastern Taiwan. Bare rock and dead coral cover the largest proportion of the bottom substrate at many sites, especially in Hsiaoliuchiu, northeastern coast and Ilan County, suggesting that reef destruction occurred several years ago. Approximately 30% of the sites showed a higher cover of fleshy and coralline algae, mostly on the northeast coast and Lanyu, suggesting a phase-shift from coral-dominated



*Average coral cover (%) has been gradually increasing around Ishigaki Island and Sekisei Lagoon, southern Japan, since 1998 when there were major losses due to coral bleaching. This increase has occurred in spite of some repeat bleaching, increasing numbers of COTS, and localised sediment pollution.*

to algal-dominated reefs. Low densities of herbivores and nutrient enrichment are the possible factors responsible for the increasing growth of macroalgae.

## STATUS OF REEF FISH

### China

There are virtually no data on changes in fish abundance over recent decades; however, interviews with fishers and divers suggest that there have been serious declines in many reef fishes on Chinese reefs. There is greater diversity, abundance and size of commercially-important reef fish species in marine natural reserves than on fished reefs.

### Hong Kong

The Hong Kong fishery as a whole is over-exploited. Although MPAs provide some protection for reef fish, they are not completely no-take zones, as original local inhabitants of the park areas are still allowed to fish – albeit under a licensing system with non-destructive gear. Nonetheless, no pre-protection data on fish diversity and abundance in most marine parks are available, so the effects of MPA designation are difficult to assess. Monitoring in Hoi Ha Wan Marine Park indicated that the fish abundance and diversity have not increased in the 8 years since the marine park designation in 1996. On the other hand, pre-designation data are

available in Tung Ping Chau Marine Park, where a comparison of pre and post MPA monitoring data shows some increases in both diversity and abundance of fish in the core marine park no-take zones in the two years since the designation of 2001. There were 100 species of fish reported from Tung Ping Chau Marine Park, including 6 grouper species; but most of these fish were small (less than 20 cm in length).

### **Korea**

There are approximately 250 fish species in the Munseom MPA, including commercially-important food fish and aquarium fish. More species (693) were found on the southern coast of Jeju-do, which represents 83% of all marine fish found in Korea. These species include warm water species and juvenile fishes that were previously unreported in Korea.

### **Japan**

There is a trend of declining fish catches in Okinawa Prefecture. However the number of fish observed in Reef Check surveys on the coral reefs show a gradual increase since 2002 – except in Sekisei Lagoon, where there was coral bleaching in 2001 and 2003.

The total coastal reef fisheries catch from Okinawa Island and the surrounding islands from 1972 to 2001 shows a steady decline in catch since a peak in the early 1980s. Since that time, there have been major advances in technology and increased effort, indicating that the fish stocks are seriously threatened; (data from Statistical Information Center of Ministry of Agriculture, Forestry and Fisheries, with distant-water fisheries data removed).

### **Taiwan**

Commercially-important fish species were in very low abundance at most sites from 1997 to 2004; the key target fish (humphead wrasse, bumphead parrotfish, and reef barracuda) were absent in all of the 32 reef sites monitored. No grouper were recorded at 78% of the reef sites, whereas they were comparatively common in the Penghu islands at 5 of 7 sites; although the population density was low and the fish were small. Grouper are commercially valuable and heavily fished by a variety of methods in the waters around Taiwan. The abundance of snappers was also very low, and none were recorded at 63% of the sites. Where they were seen, there were only one or two individuals in 500 m<sup>2</sup>. These data are clear evidence of over-fishing. Similarly the abundance of butterflyfish was much lower than on most Indo-Pacific reef sites (2-4 fish per 100 m<sup>2</sup> compared to 6-8 fish per 100 m<sup>2</sup>). Such low fish densities indicate that the reefs are under pressure from aquarium fish collectors.

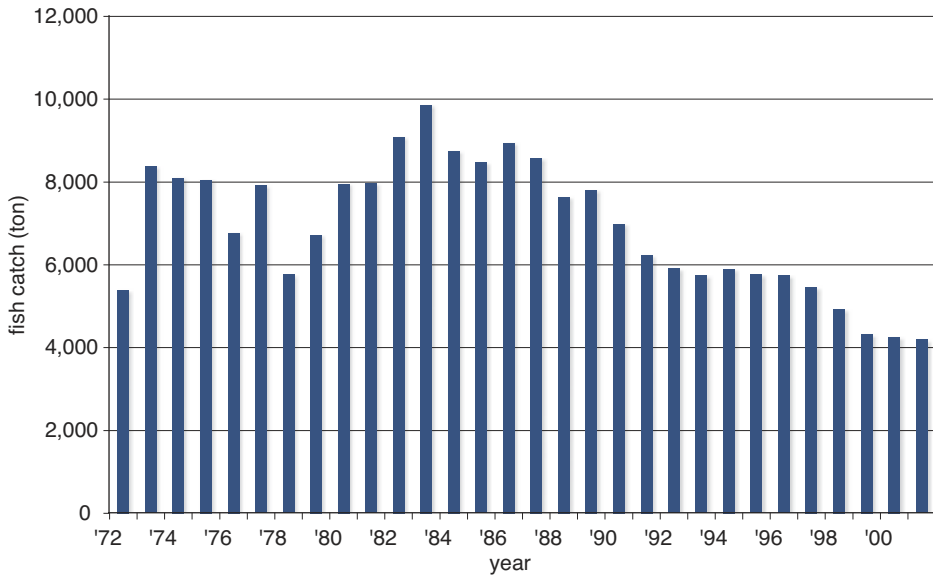
## **STATUS OF RESOURCE USE**

### **China**

Collection of corals for sale as decorative items is quite common, but fishing is the main activity associated with Chinese coral reefs. Diving tourism is becoming more popular, especially in places like Sanya, Hainan Island. No detailed data, however, are available for assessment.

### **Hong Kong**

The mining of corals for building materials is not common in Hong Kong and not perceived as a problem. There were historical records of corals being burnt in kilns to produce lime. Collection of corals for sale as curios, or for aquaria, has been reported, but there are no detailed data. Fishing remains the main human ongoing harvesting activity on Hong Kong coastal coral communities, with the predominance being subsistence fishing by families using nets, lines and traps. There is recreational fishing also using hook and line or spearfishing.



*The total coastal reef fisheries catch from Okinawa Island and the surrounding islands from 1972 to 2001 shows a steady decline in catch since a peak in the early 1980s. Since that time, there have been major advances in technology and increased effort, indicating that the fish stocks are seriously threatened; (data from Statistical Information Center of Ministry of Agriculture, Forestry and Fisheries, with distant-water fisheries data removed).*

There is increasing interest in eco-tourism and raised awareness within the community of the need to conserve reef resources for their tourist potential. This trend is likely to increase in the coming years with more and more people learning how to scuba dive. There is also an increasing trend for schools to organise activities related to the marine environment. Glass-bottom boat viewing is becoming more popular, with many companies running glass bottom boat tours for tourists and weekend vacationers.

### **Korea**

The gorgonian coral, *Antipathes japonica*, has been in wide traditional use as an ornament or as a charm in houses to drive away evil spirits. Now there is recognition that soft corals attract other marine organisms by providing a structural habitat and also a source of novel chemical compounds. Soft corals form attractive underwater scenery for tourists, especially the mix of temperate, tropical, and subtropical species around Jeju. The Munseom area, southern Jeju, is a particularly important habitat of corals and fishes. Since 1988, these areas have attracted increasing numbers of tourists that see the reefs from submarines, e.g. 900,000 people have used these submarines. However, there has been collateral damage to the soft coral communities. The increases in scuba diving and submarine use pose a long-term threat to the biodiversity, but there has been insufficient long-term research and monitoring to verify the effects.

### **Japan**

Marine tourism is a rapidly growing industry in coral reef areas, with steady increases in visitor numbers, and the potential for increased pressures on coral reef resources. Recently, coral transplantation has become a special attraction in Okinawa. It has been promoted by tour

operators with the object of restoring damaged reefs. Coastal and coral reef fisheries were once active, but have recently declined, and it is apparent that overfishing has reduced the stock size. Aquaculture is now one of the main uses in shallow coral reef waters. 'Mozuku' and edible brown algae and prawns are commonly farmed in Okinawa, but the use of aquaculture to enhance natural stocks is now occurring. Hatcheries are raising juveniles of desirable species (e.g. swimming crabs, sea urchin, emperor fish, button shells and giant clams) and releasing them into the coastal waters of the Ryukyu Archipelago for resource management. Salt production from coastal seawater is becoming a viable business in Okinawa, Amami and Ogasawara Islands.

The International Coral Reef Research and Monitoring Center was established by the Ministry of the Environment and develops educational materials and programs on coral reef conservation for schools and the public. The Nago Elementary School in Okinawa conducts a 7-year program focused on closer interaction with coral reefs, and the Sea Farming Center of the city of Hirara also runs educational programs for school students, to raise environmental awareness of the need for fisheries management. School education and public awareness is improving, however, more educational publications and programs are required. The Japan International Cooperation Agency (JICA) has run courses in coral reef conservation every year since 1996, to train administrative officials and technical experts from countries with coral reefs.

### **Taiwan**

All reef areas in Taiwan have been over-fished, and fishery resources were clearly depleted at least 10 years ago. This has been confirmed in Reef Check surveys from 1997 to 2004, where the abundance of target fish was very low on the reefs. Most reefs also suffered from intensive aquarium fish collection. Scuba diving and snorkelling, however, have flourished during this time, especially on northeast and southern Taiwan reefs – Lutaou, Lanyu and Penghu Islands are used intensively for tourism. The tourism trend is increasing in parallel with the growing demand for marine recreation.

## **PHYSICAL ENVIRONMENT OF EAST ASIAN CORAL REEFS**

### **Hong Kong**

Hong Kong has a subtropical environment, with summer water temperatures near 30°C, but the winter minimum can be as low as 13°C. There is a distinct wet season from March to September, and autumn and winter are usually dry. On average, 5 to 6 typhoons have hit Hong Kong per year in the last 18 years, with at least one being severe, recording wind gusts to 130 km/hr. Most storms, however, do not cause extensive destruction of coral communities. The Agriculture, Fisheries and Conservation Department of the Hong Kong Government and university research laboratories are monitoring physical parameters in the marine parks. There are large annual variations in many of these parameters, including dissolved oxygen and nutrient concentrations, but no clear trends are discernible.

### **Korea**

Soft corals were once dominant only on vertical surfaces on Jeju Island, whereas brown algae covered horizontal surfaces from 5 to 25 m depth. However, since 2000, the soft corals have been replacing the algae. This is possibly because of turbidity changes due to construction to extend the harbour.



## Japan

Mean midsummer seawater temperatures in July and August in 1998, 2001 and 2003 were much higher than those in 1999, 2000 and 2002 in Ishigaki. Typhoons are frequent around Okinawa and southern areas of mainland Japan, with about 11 typhoons approaching within 300 km of Japan annually. This results in regular physical damage to coral communities and also severe sediment discharges onto corals.

## Taiwan

The coral reefs are frequently impacted by typhoons, with increased sedimentation from terrestrial runoff being another major stress on coral reefs around Taiwan and Penghu Islands. Sea surface temperatures are constantly monitored at major port areas, but there is no clear trend over the past 20 years. Salinity and turbidity are measured intermittently, and assessments of turbidity show no long-term trends in satellite images, but there are anecdotal reports of environmental damage.

## STRESS AND DAMAGE TO CORAL REEFS

### Sediments and Nutrients (land-based)

#### China

Sedimentation, freshwater incursion, and sewage outflows have adversely damaged China's reefs, particularly near the mainland. Poor land-management practices are the major causes of these problems. Pollution from urban sewage discharged largely untreated into Daya Bay has resulted in it being highly polluted. Untreated industrial waste also contributes to marine pollution, and organic and metal pollution are believed to be responsible for the loss of coral communities in Daya Bay.

#### Hong Kong

The main marine pollution problems in Hong Kong are:

- high sedimentation due to dredging and land reclamation;
- high nutrient concentrations due to the release of untreated sewage; and
- high heavy metal concentrations in industrial effluents.

Dredging of sediments during large reclamation projects, like the Chek Lap Kok Airport, have generated excessive siltation effects. The extensive mortality of corals in South Ninepin is attributable to heavy siltation from the dredging in Tung Long Wan Borrow area in 1994. Siltation effects on corals in Po Toi, Sung Kong and Cape D'Aguiar in the southeast are currently being monitored. There are some reports of sediments accumulating on *Acropora* corals around the dredge sites. Recent reclamation for port development is suspected to have caused the mortality of fish and partial mortality of corals in coral communities in the northeast – including those within the marine parks.

#### Korea

The major factors threatening marine life, including corals, are suspended material from coastal development and construction, and land-based organic pollution.

#### Japan

Sedimentation is still a major threat to coral reefs and coral communities, and has not been resolved in the Ryukyus Islands. Severe soil runoff also occurs off mainland Japan due to

cleared lands, agriculture, road construction, and as a result of goats clearing native vegetation. The runoff of red soils from Kohama, Iriomote, and Ishigaki Islands continues to disturb the potential for healthy recovery of coral communities. Silt deposition is relatively high, coral coverage is low on reefs on the northeast and southern coasts of Kohama Island, and red soil sediment levels are similar or increasing in Sekisei Lagoon and Ishigaki Island. Additionally, silt is piling up on the sea floor at Yonara Waterway, where the reefs have a high cover of *Acropora*. During a typhoon in September 2001, there was a large deposition of sediments from Tosashimizu, Otsuki, and Sukumo into the Ashizuri Sea, and this heavily damaged the Tatsukushi Marine Park with considerable coral death. Similar landslides at the Shirigai Marine Park buried living corals, and there is 3 m of accumulated red soil sediments in Fukuro Bay in Ogasawara Islands that has killed many *Lobophyllia hemprichii* colonies.

### **Taiwan**

Coastal areas around Taiwan have been intensively exploited for aquaculture, road construction, resort building, and agriculture, with soil erosion high and frequent landslides resulting in large amounts of sediment and nutrients being transferred to reef areas. Sewage of most coastal towns and villages is often untreated and discharged into reef areas. This has caused serious nutrient enrichment, especially in northeast and southern Taiwan, and Hsiaoliuchiu.

### **Damaging Fishing Methods**

#### **China**

Overfishing with hook and line, monofilament nets or traps is the most serious threat to reef fishes, and few fish exceed 10 cm in length. This overfishing and especially destructive fishing practices have badly damaged coral communities around Hong Kong and Xisha islands, causing most high-value fish species to become locally extinct.

Traps and monofilament nets also snag corals and cause damage to them when retrieved. Abandoned nets can smother corals. Other threats include bomb fishing, which has occurred in the South China Sea for more than 100 years, and recently there has been the use of cyanide to catch fish. Illegal fishing and the sale of living corals for the aquarium trade are problems around Hainan Island. Bomb fishing has been widely practiced in Hainan Island and the remote Nansha Islands, which has resulted in 50-80% coral mortality. Cyanide fishing by large-scale commercial operators and for collecting aquarium species occurs in the remote Xisha and Nansha islands.

#### **Hong Kong**

Although a significant proportion of fishing by Hong Kong fishers is conducted in waters adjacent to Hong Kong, e.g. in the East China or South China Seas, trawling, gill-netting, purse-seining and trapping using different types of cages are still practiced within Hong Kong territorial waters – especially by family-based, subsistence fishers. Fishing pressure is therefore very high in coral communities. Although fishing using explosives is less common now than 10 years ago, it is still occasionally being practiced. Furthermore, the use of nets over coral areas often results in nets being entangled on corals. These nets may then be left and continue to catch fish and other invertebrates as ‘ghost nets’. Illegal fishing within the marine parks is still rampant.

#### **Taiwan**

Although bomb and poison fishing methods have been officially banned, there are still sporadic reports of these illegal methods, especially in southern Taiwan and offshore islands, including

Hsiaoliuchiu, Lutaο, Lanyu, Penghu Islands and Dongsha Island. Gill nets are frequently used in most reef areas and discarded fishing gear is frequently found. There are preventive measures, including intensive inspections and patrols by the coast guard to reduce illegal fishing; however, the effectiveness of the enforcement of laws varies considerably.

### **Korea**

Over-fishing and damaging fishing methods, like spearfishing, are still prevalent, although decreasing. Most information comes from observations and reports from divers, fishers, government agencies and NGOs. Commercial fish farms are increasing near MPAs due to the high economic potential of tourism. Over-fishing and uncontrolled collecting now involves the use of scuba equipment.

### **Japan**

Fisheries Laws have been developed against destructive fishing practices, such as bomb and cyanide fishing. These practices are not common in Japan because of effective management by the Fisheries Cooperative Associations.

### **Anchor and Trawler Damage, Other Damage**

#### **China**

There is sporadic damage from anchors and physical damage by recreational divers on remote coral reefs.

#### **Hong Kong**

There are no data on anchor and trawler damage to Hong Kong coral communities. There is, however, anecdotal evidence that indicates that anchor damage is quite significant at popular destination sites for yachts and pleasure crafts, e.g in Un Kong Wan in eastern Hong Kong waters and in Chek Chau in Northeastern waters. Although anchoring is restricted within the marine parks, illegal anchoring does occur. The frequency, however, is not known. More recently, there are claims of coral damage caused by glass bottom boats. Other damage by eco-tourists and swimmers standing on the coral heads may also be substantial but this has not been assessed.

#### **Korea**

There is no control over spearfishing by divers, or collection for scientific purposes. There is also damage from recreational divers and negative impacts of tourist submarines on soft corals growing on vertical surfaces.

#### **Japan**

Overuse of coral reefs is clearly apparent at Shiraho in Ishigaki Island, where tour boats that take visitors for snorkelling have left 200-300 m depressions around anchoring sites. Unfortunately, there are no regulations on the use of glass-bottom boats or snorkel tours in Shiraho, and snorkelers and boat anchor damage to the reefs continues to increase. However on nearby Kabira, snorkelling is not permitted from glass-bottom boat tours, and this is the apparent reason for improved reef health. In Yaeyama Islands, local fishermen report that some coral reefs have been severely damaged by anchoring and groundings of foreign vessels.

#### **Taiwan**

Anchor damage is found sporadically on most reefs, however, bottom-trawlers have caused severe damage to coral reefs in Penghu Islands by dragging destructive gear over the reefs. Trampling and mechanical breakage of corals by divers and tourists is a serious problem at diving hotspots in Lutaο, Penghu, and southern Taiwan.

## **Development Damage to Coral Reefs**

### **China**

Development along the coastline is causing direct damage to coral reefs e.g. local governments blasted Mabian Zhou, Daya Bay for the oil industry in the late 1990s, and the damage is still evident, even though coral transplantation has been carried out to reverse the damage.

### **Hong Kong**

Coastal reclamation of large areas has been conducted in Hong Kong for the last 20 years; frequently by the Hong Kong Government. Out of the total land area of 1100 km<sup>2</sup> in Hong Kong, more than 60 km<sup>2</sup> is reclaimed land. Most of this reclaimed land is around Victoria Harbour, western waters and Tolo Harbour in the Northeast. The damage from reclamation is not extreme, as most coral communities are found in the eastern and northeastern shores. However, reclamation is only part of the picture; the mining of materials for use in reclamation is a major problem. Materials used in reclamation include construction wastes, earth and rocks dug out from mountain borrows, and marine sand. The reclamation for the new Hong Kong airport in Chek Lap Kok in the mid 1990s was one of the largest coastal reclamation projects in the world. Much of the material for the project was the marine sand from Hong Kong eastern waters, where dredging of marine sand caused extensive sedimentation on the coral communities along the eastern shores.

The recent development of a container terminal in Yim Tin, Shenzhen, north of Hong Kong, also involved extensive reclamation. Although there was no detailed monitoring on the Hong Kong side, anecdotal evidence indicates an increase in sedimentation on coral communities in the northeast. The broader effects on the Hong Kong marine parks remain to be seen.

### **Korea**

Local divers have reported that the currents between main island (Jejudo) and Munseom islet have unexpectedly changed due to the construction to extend Seogwipo harbour.

### **Japan**

Coral distribution is decreasing in some small bays, owing to destruction and sedimentation during the construction of fishing ports in Tsushima and Iki islands. Some corals have been degraded by red soil running off road construction works. There were once well-developed coral communities in Higashi Bay, on Haha-jima of Ogasawara Islands, but these disappeared during harbour development, although this has not been confirmed by monitoring studies. There have been 69 ha reclaimed at Hirara and the town of Shimoji prior to 2002, with the largest single development being 32 ha for a tourist resort by the city of Hirara, from 1995 to 2002.

### **Taiwan**

Monitoring of the construction of the Fourth Nuclear Power Plant on the northeast coast of Yenliao is indicating possible damage to coral reefs. Similarly, construction of fishing ports and a coastal highway in northeast and east Taiwan has damaged the reefs.

## **Coral Bleaching and Diseases**

### **China**

There were extensive coral diseases in Yongxing Island (Paracel Islands) in 2002 and in Zhubi Island (Spratly Islands) in 2004. Mass coral disease was observed in Yongxing Island (Paracel Islands) in 2002 and in Zhubi island (Spratly Islands) in 2004.

### Hong Kong

No extensive coral bleaching has been observed in Hong Kong, not even during the La Niña year of 1998. There has been some paling in colour, especially in massive corals like *Porites lobata* or *P. lutea*. Bleaching of select coral species, like *Goniopora* spp, *Hydnophora excesa* and *Montipora* spp, has also been reported, but was usually in isolated colonies. Bleaching was more frequent in summer, but paling of colour in other massive corals may happen in the summer or in winter. The loss of colour is therefore not only associated with increased temperature in summer, but may also be associated with decrease in temperature in the winter. Most of the bleached or discoloured corals recover and little coral mortality is attributed to bleaching.

There has been no detailed monitoring on coral disease, although tumours in some dominant coral species like *Platygyra sinensis* are prevalent. No black-band or white-band diseases have been observed within the marine park areas. The failure to observe such disease may simply be a result of a lack of expertise in this area.

### Korea

No coral bleaching or coral diseases have been reported in Korea.

### Japan

Coral bleaching caused by high water temperatures occurred in 2001 and 2003 in Japan after the mass bleaching event in 1998. In 2001, a warm water mass developed near Okinawa and bleaching was observed in the Ryukyus, and Kerama Islands in July 2001. Coral mortality was 10% in Maenohama, compared to 25% in 1998. The average rates of coral bleaching in Sekisei Lagoon was 21.6% in 2001 and 28.3% in 2003, however, mortality was only 2.7% in 2003. Some coral colonies remained pale in 2003 after bleaching in 2001, and this may indicate continued, long-term stress for the corals in Sekisei Lagoon. Corals in all the Ishigaki monitoring sites were affected by bleaching in 2003, with the average rate being 13%. A mass coral-bleaching event in Haha-jima was observed in 2003, after minimal bleaching in 1998 on Chichi-jima and Haha-jima of the Ogasawara islands. Many colonies of *Acropora donei*, one of the dominant coral species, died in 2003 while *Porites* colonies recovered after bleaching. Also there was little bleaching in Amakusa in 2003. No bleaching was observed in Ashizuri and Kushimoto in mainland Japan, and corals on Kerama Islands showed little bleaching in 2003.

Coral disease is an emerging threat to coral reefs in the Ryukyu Islands. A new type of tumour was identified on *Porites lutea* in Okinawa in 2002, and a large coral community with tumours was found off Yonaguni Island and around the Kerama Islands in 2003. Different diseases were reported also in Sekisei Lagoon during annual monitoring. These included tumours, black-band disease, and white syndrome on branched, tabulate and finger-like *Acropora*. Coral disease was observed at 30% of the monitoring sites in 2003, but the cause is unknown, and further research is required urgently.

### Taiwan

Extensive coral bleaching was observed in southern Taiwan, Penghu Island, and Hsiaoliuchiu reefs following heavy rainfalls during typhoons in mid 2004. Apparently these bleaching events were related to a significant reduction in available light in the water column, due to high sediment turbidity. Disease outbreaks have not been reported previously in Taiwan, however, some minor coral diseases, including tissue or skeleton abnormalities, were noticed in northeast, east, and south Taiwan, and offshore islands such as Hsiaoliuchiu and Penghu Islands. It is apparent that the incidences of coral diseases are rapidly increasing, indicating an urgent need for coral disease studies in Taiwan.

## Outbreking or Invasive Organisms

### Hong Kong

The major coral predators in Hong Kong are the gastropods *Drupella rugosa* and *Cronia margaritcola*. Some aggregations of these snails have been observed, and outbreaks have been reported on isolated coral heads. Their numbers are generally small and their distribution quite restricted. There appeared to be significant positive correlation between water temperature and gastropod activities.

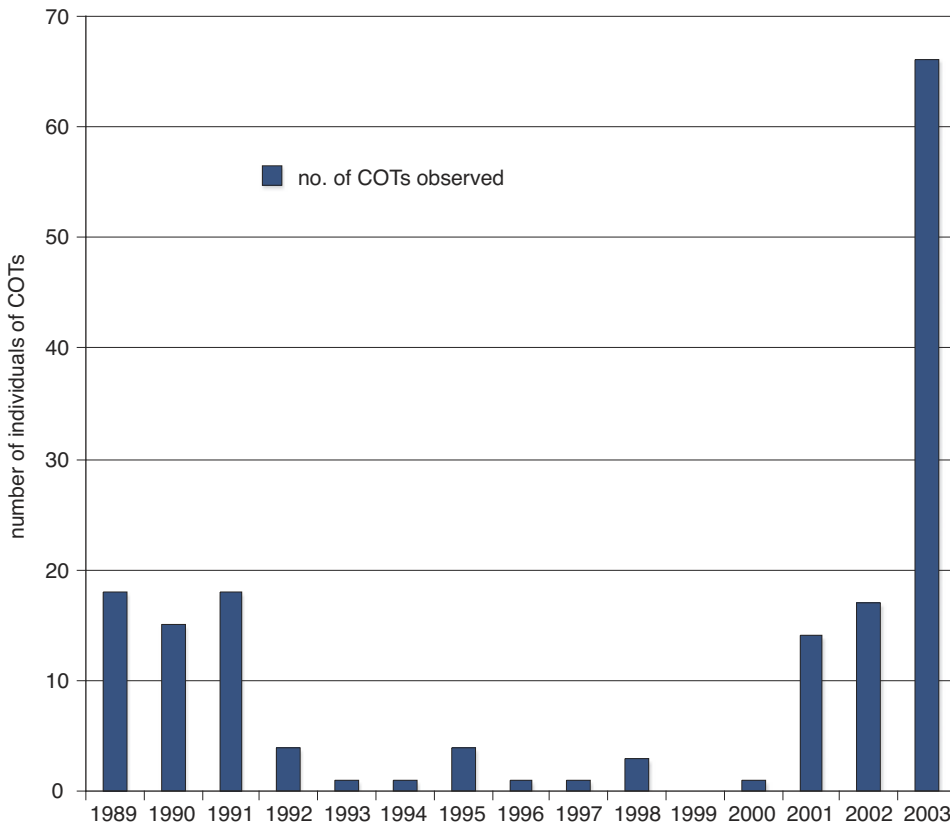
### Japan

An outbreak of COTS occurred from 1970 to 1980 in Ryukyu Archipelago and destroyed most of the coral communities. Between 1973 and 2002, 1.55 million COTS were removed in the Amami Archipelago by Amami Oshima Marine Park Marine Resource Conservation Association, a local NGO. Although 9 million COTS were removed in Setouchi during the 1980s, the population increased again in 2001. Okinawa Island also has had chronic populations of COTS since the 1970s, and an outbreak of COTS was observed at Onna Village, west Okinawa Island in the 1990s, and it has continued to spread around the Island. Many aggregations of COTS have been observed in the Kerama Islands since 2001, along the east coast of Okinawa Island in 2002, and local diving operators in Kerama removed 120,000 COTS in 2002 and 2003. There were signs of increasing COTS populations in Yeayama Archipelago in 2001, and numbers are increasing rapidly, e.g. 66 individuals were observed during monitoring in 2003, a 4-fold increase since 2002. Small aggregations of COTS were observed in this area in 2004, and also other groups were observed in Kumamoto, Miyazaki and Kagoshima in Kyushu, Kochi in Shikoku, and Wakayama in mainland Japan from 2001 to 2003. These COTS outbreaks appear to be dispersed by the Kuroshio Current flowing north.

The coral-eating gastropods, *Drupella*, are a serious predator of high-latitude corals. A severe outbreak of *Drupella* was observed in Miyake Island in Izu Islands, Miyazaki and Kumamoto in Kyushu, and the west coast of Shikoku in late 1970s to 1980s. Some areas have retained *Drupella* populations since the outbreak, e.g. damage by *Drupella* was reported on east coast Shikoku in 2001. Approximately 100,000 to 200,000 individuals of *Drupella* were collected per year in the west coast of Shikoku at the peak of an extermination program from 1995 to 2000. In Kyushu during 2003, more than 40,000 *Drupella* were removed in Ushibuka Marine Park. *Drupella* cause less damage than COTS on the true coral reefs to the south. Aggregations of *Drupella* were observed in Sekisei Lagoon in 2002 and 2003 in areas receiving other disturbances, such as soil runoff, bleaching, and typhoons. Although there was no significant damage from *Diadema* on corals in Ryukyus, severe damage was reported to northern coral communities. Damage to *Acropora tumida* by *Diadema setosum* has been observed at Suruga Bay in Shizuoka, Honshu, with the damage estimated to be 59 kg per month of erosion.

### Taiwan

COTS have been observed occasionally on the reefs around Taiwan. High densities of *Drupella* were observed at one site in Penghu Islands; however, it is not considered an outbreak since it is rare on other nearby reefs. An outbreak of a sea anemone, *Condylactis nanwanensis*, was noticed in Nanwan Bay, southern Taiwan, and is possibly an invasive species from the Caribbean introduced via the aquarium trade. This sea anemone has caused severe damage to coral reefs since it destroys coral tissue and weakens coral skeletons.



*The number of crown-of-thorns starfish (COTS) has varied considerably in Sekisei Lagoon, Southern Japan from 1989 to 2003. The elevated numbers from 1989 to 1991 are the remains of a massive outbreak in the 1970s, and the recent increases in numbers may indicate another serious outbreak.*

## Coral Damage from Natural Events

### Hong Kong

Typhoons cause some damage to coral communities and usually overturn a few coral colonies. The occasional strong typhoon with wind gusts to 130 km/hr does cause damage to corals, e.g. those in Tung Ping Chau Marine Park.

Several suspected hypoxia events have been reported in Hoi Ha Wan and Yan Chau Tong Marine Parks in the last 10 years. The worst event was in 1994, which seriously affected the corals of Hoi Ha Wan causing extensive mortality (up to 83%) of corals in deeper water. A suspected hypoxia event was reported in early 2004 in north-western Yan Chau Tong Marine Park. The corals were stressed with large-scale partial mortality and a major decrease in coral cover. There was mortality of fishes and invertebrates in both Hoi Ha Wan and Yan Chou Tong Marine Parks at the same time.



### **Taiwan**

Occasional coral damage from mechanical breakage and sediment burial due to typhoons has been observed at monitoring sites, with high levels of variability. Coral communities in protected habitats are particularly vulnerable to typhoons, e.g. the coral communities at Chitou, Penghu Islands and Tiaoshi, Nanwan Bay suffered up to 90% coral mortality during Typhoon Chibi in September 2001, and have not recovered since.

### **Korea**

An average of 3.1 typhoons hit the Korean peninsular near the southern coast of Jeju each year. The harbour extension in Seogwipo was added to reduce damage from the typhoons in the summer rainy season. Strong storm surges can remove the corals from the rocky cliffs, but there has been no measurement of damage in national surveys.

### **Japan**

Typhoons are common in Japan with an average of 11 typhoons approaching within 300 km of the Japanese Archipelago annually, predominantly in August and September. Damage from typhoons varies considerably, e.g. in 2002 and 2003, the highest mortality of corals caused by typhoons was less than 10% in Sekisei Lagoon. In 2004, 21 Typhoons approached the Kochi Prefecture, compared to 15 in 2003. There was direct damage to the coral communities, especially high fragmentation of *Acropora hyacinthus*, however there was little mortality, although many colonies remain pale. Sediment runoff from the heavy rains may have long-term effects on these communities. The volcanic eruption on Miyake Island in 2000 deposited up to 20 cm of volcanic ash on the sea floor, and most *Acropora* colonies were killed on the reef and 80% of tabulate *Acropora* were killed offshore from the harbour.

## **POTENTIAL THREATS TO CORAL REEFS (REEFS AT RISK THREAT INDICATORS)**

### **China**

The Reefs at Risk in South East Asia (RRSEA) analysis in 2002 reported that 92% of China's reefs were under significant threat. Over-fishing is the most pervasive threat affecting more than 75% of the reefs. Sedimentation from poor catchment management was estimated to damage 40% of all reefs, and coastal development endangers more than 28%.

### **Hong Kong**

Based on the Reefs at Risk indicators, about 15% of Hong Kong coral communities are subject to a very high degree, and another 80% to a high degree of potential threat from coastal development. Similarly about 10% of these reefs are under very high threat, and another 80% are under a high threat of marine based pollution damage. Sedimentation is a serious threat as well, with 5% of the communities threatened at a very high level, and 60% under threat of a high degree of siltation damage. All of the coral communities are over-fished, and 80 to 90% of them are exposed to damaging fishing practices.

### **Taiwan**

A revision of the 5 RRSEA indicators reveal that all reefs are threatened, with over-fishing and destructive fishing threatening 75% of reefs, and sedimentation and coastal development each threaten 50% of the reefs.

### **Korea**

Assessment of the 5 RRSEA indicators is difficult, as there is no regular monitoring.

## Japan

Sedimentation from terrestrial runoff was the most serious threat to Japanese reefs under the RRSEA analysis of 2002. Annual monitoring showed that the sediment loads have not changed much around Ishigaki Island and Sekisei Lagoon since 2000, and there was catastrophic coral mortality after heavy rain in Okinawa, Ishigaki, and on mainland Japan (Kochi) in 2001. High potential sediment input remains as one of the most serious threats in Japanese waters.

The assessment suggested that over-fishing is the most pervasive cause, threatening over 70% of Japanese reefs, and coastal fish catches have declined in Okinawa since 1984, and show the same trend in 2001, indicating high pressure on fisheries resources. The RRSEA analysis showed that nearly 80% of the reefs were at risk from human activities and there has been no change since 2002.

## CORAL REEF MANAGEMENT

### Marine Protected Areas

#### China

There are 3 Marine Coral Reef Reserves on mainland China, and more MPAs are planned. These marine reserves are 'no-take' areas with only approved scientific research allowed within the boundaries.

The Sanya National Coral Reefs Nature Reserve (5568 ha) near Sanya City, Hainan Province, was established in 1990, and is the only national coral reef reserve. The average fish biomass is more than 15 kg/ha, with a density of 49 fish/ha. Coral-dependant benthos species in the area are rich, forming a typical tropical marine ecosystem. There are 41 coral species and 134 fish, as well as over 60 large benthic algae. Dongshan Bay Provincial Coral Reefs Nature Reserve (11070 ha) in Dongshan Bay, Fujian Province was established in 1998, with only 6 hard coral species and 12 species of hexacorals/octocorals – it is relatively low in biodiversity. Denglujiao Provincial Coral Reefs Nature Reserve in Guangdong Province was established in 2002 to protect coral reefs.

#### Hong Kong

There are currently 4 Marine Parks (Tung Ping Chau, Hoi Ha Wan, Yan Chau Tong, and Sha Chau and Lung Kwo Chau) and one Marine Reserve in Hong Kong. Coral communities are the main target of protection in Tung Ping Chau (260 ha) and Hoi Ha Wan (260 ha) Marine Parks. Several other sites have been surveyed and are targeted for protection in the future. These include Fan Lau (Southwest Lantau), Soko Island Group, Southern Lamma Island (all in southwest and south of Hong Kong), Kat O Chau and Ngo Mei Chau, Tai Long Wan, Long Ke Wan, Bluff Island and Nine Pine Island Group.

**Taiwan:** Most of the reef areas are within national parks or national scenic areas, with management entrusted to: the Kenting National Park in south Taiwan; the NE Coast National Scenic Area; the East Coast National Scenic Area; Tapengwan National Scenic Area; and Penghu National Scenic Area. Unfortunately, the effectiveness of management is poor, because these authorities lack adequate laws to protect the reefs and enforce laws. The revision of laws and establishment of MPAs with effective management is under planning and discussion by governmental administrations. Dongsha Marine National Park was established in 2004 (Box p 294).

### A FUTURE FOR A DESTROYED REEF: DONGSHA NATIONAL PARK, SOUTH CHINA SEA?

In less than 10 years, the isolated and beautiful Dongsha Atoll (or Pratas Island) was virtually destroyed because of excessive and destructive fishing. The Taiwanese government declared it as a marine national park in March 2004, but it is not known yet whether the coral reef will recover to its former beauty. Dongsha is the most northern atoll in the South China Sea at 20°40'N and 116°50'E; it is 28 km in diameter and covers 600 km<sup>2</sup>. When the atoll was surveyed in June 1994, there was approximately 80% coral cover of 137 species along with 369 fish species. Subsequently the atoll was fished intensively with 7976 boats seen fishing within and around the atoll in March and April, 2001. They fished with gill nets, long lines, purse seines, and destructive methods such as bombs and cyanide. Monitoring has revealed the devastating effects of this fishing: 45 coral species and 118 fish species were recorded at one reef site in 1994, but only 3 coral and 32 fish species were seen in 1998. More than 90% of the reef communities had been killed and replaced by filamentous and macro-algae. The food web had virtually collapsed so that only low trophic level fish, such as algal and plankton feeders remained in 2002.

Year	Live coral cover	Macroalgae	Fish
1994	80%	<10%	All trophic groups
2002	<10%	>70%	Mostly herbivorous fish

In 2001, there were thick beds of dead corals all over the reef, with no trace of live colonies between 1-7 m depth in the lagoon. However, there was 25% live coral cover at 10 m depth, mostly *Echinopora* spp., fungiids, and poritids, and there were 107 species of new coral recruits, showing strong potential for recovery. The atoll and an area out to 100 m depth line have been declared a highly protected zone, and the area out to 12 miles from the edge is a general control zone.

#### Korea

In 2001, two islets, Munseom and Bumseom of Jeju-do, were designated as Natural Monument Protection Areas to protect marine life, including corals. The southern coast of Seogwipo, including Munseom, Bumseom and Supseom, was designated as a Wetland Protection Area under the Wetland Protection Act by the Korean Government, and MAB (Man and Biosphere) by UNESCO in 2002. As a result, 9 wetland protected areas have been designated since 2001. Seogwipo coastal area is protected mainly for the corals and underwater scenery, with the goal of raising public awareness for local stakeholders and conservation planning in local government, as well as central government.

#### Japan

There are 52 MPAs containing 2924 ha of coral reefs and coral communities in Japan. These MPAs include Marine Park Zones under National Parks and Quasi-National Parks, Nature Conservation Areas, and Fisheries Protected Waters. National Parks and Quasi-National Parks are designated under Natural Parks Law. There are 47 Marine Parks on coral reefs and coral communities. The newest MPA is Kurio in Yakushima, Kagoshima Prefecture, designated in 2002 to protect distinctive underwater scenery and fish and coral diversity. Sakiyama Bay of

Iriomote Island is a Nature Conservation Area under the Nature Conservation Law. The Fisheries Protected Waters are regulated by the Fishery Regulations of Prefectural Governments, and aim to protect and manage fisheries resources. There are two Fisheries Protected Waters with coral communities in Ishikgaki Island in Okinawa Prefecture, and two sites in Kumamoto Prefecture. Community-based MPAs have been established at local villages in Kerama Islands, including one managed by the local Fishery Cooperative in Zamami village, to protect coral reefs from overuse by divers. They will regulate access and use for diving for a few years to enhance the recovery of corals. Their management also includes controlling COTS outbreaks.

## **Monitoring**

### **China**

Considerable research in biology, geomorphology, and geology has been undertaken since the 1950s; mainly through external research scientists from Russia (1957-1960), Australia (1984), and Germany (1990, 1992). The studies have included coral status surveys, with most of the data being qualitative and descriptive, but there were some quantitative data collected in 1993, 1998 and 2004. A few academic institutions, notably South China Sea Institute of Oceanology, Chinese Academy of Sciences, in addition to the government, conduct small-scale monitoring programs on corals, fishes and basic environmental parameters. Coral community surveys were conducted at Daya Bay, Guangdong Province and in the Luhuitou fringing reef of Sanya City, Hainan Island. The Luhuitou fringing reef has been the most studied coral reef in China. Transect surveys were conducted also at Xiasha Islands and Yongxing Island in 2002. A Reef Check workshop was held in Sanya, Hainan Province in 2000, and the government set up provincial monitoring and management programs following the training.

### **Taiwan**

Monitoring of coral reefs has been conducted by the Taiwanese Coral Reef Society using Reef Check surveys since 1997, and has been sponsored by the Administration of Fisheries of the Taiwanese government. Another long-term ecological research program was launched in 2001 to study and monitor the changes of coral reefs in southern Taiwan. The National Science Council of the Taiwanese government sponsors this program, and data are managed by the Research Center for Biodiversity, Academia Sinica (<http://140.117.92.194/Iter>).

### **Hong Kong**

Monitoring of the health of Hong Kong marine parks is ongoing, with the Agriculture, Fisheries and Conservation Department (AFCD) of the Hong Kong SAR Government as the lead government agency. AFCD funds research teams from the Marine Science Laboratory of the Chinese University of Hong Kong to monitor the parks, with the current monitoring focused on the marine parks in the northeast: Tung Ping Chau; Hoi Ha Wan; and Yan Chau Tung. Monitoring includes permanent photoquadrats, line intercept and random point transects. Monitoring of Cape D'Aguiar Marine Reserve, especially the fish abundance and diversity, is undertaken by AFCD. Other research scientists in Hong Kong regularly conduct scientific studies within the marine parks and marine reserve. WWF Hong Kong has an ongoing coral monitoring program within Hoi Ha Wan Marine Park to assess potential damage from educational activities at the Marine Life Centre in the Marine Park. Reef Check has been conducted in Hong Kong, and since 2000, annual monitoring has been coordinated by AFCD. Teams of volunteers surveyed 33 sites around Hong Kong and received considerable publicity.

**Korea**

Monitoring and reporting for the management of the Wetland Protected Areas are planned, however, regular monitoring is not considered. The only information comes from anecdotal comments of local divers. The effects of submarine tourism on benthic community structure, including corals, has not been considered, although this is the most destructive factor on the southern coast of Jeju.

**Japan**

Reef Check surveys have been conducted in Japan since 1997 by the Coral Network. The number of sites and participants has increased to more than 300 participants surveying 22 sites. Other monitoring programs on corals have been conducted by local groups of volunteers: Yaeyama Archipelago (Yaeyama Coral Reef Conservation Council); Ishigaki Island (WWF Japan); Ushibuka in Kumamoto Prefecture (Ushibuka Diving Club); Otsuki in Kochi Prefecture (Otsuki Park Volunteers); and Yaku Island (Yakushima Marine Organism Research Workshop). Research Institutes also conduct monitoring, e.g. the Amami Marine Museum in Naze, Amami Archipelago, the Akajima Marine Science Laboratory in Kerama Islands and the Ishigaki Tropical Station of Seikai National Fisheries Research Institute in Ishigaki monitor the reefs around their institutions. There are monitoring programs also conducted by the marine laboratories of Universities, such as the Sesoko Marine Station, University of Ryukyus, and the Amakusa Marine Biological Laboratory of Kyushu University. Local governments also conduct monitoring programs for coral conservation and management, e.g. Hirara City in Miyako Island has monitored coral damage by tourists on Yabiji Reef; and the Okinawa Prefectural government has developed a manual of monitoring on COTS. The Ministry of the Environment has a long-term annual monitoring program on corals in Yaeyama Archipelago, initiated by the Yaeyama Marine Park Research Center in 1983. The Ministry has been developing a national monitoring program on corals in all the regions of Japan since 2003, and this started at 24 sites in 2004.

**Legislation****China**

There are a series of laws and regulations for coral reef protection and management, such as:

1. The State Law of Marine Environment Protection issued in 1983, and new revised edition issued in 2000;
2. The Hainan Province Regulation of Coral Reef Protection issued in 1998; and
3. The State Law of Ocean Use Management issued in 2001.

These demand that all coastal development programs need the accord of the Division of Marine Functional Zonation of the government.

**Hong Kong**

Several Hong Kong government agencies provide protection for Hong Kong coral communities: the Wild Animal Protection Ordinance; and the Animals and Plants (Protection of Endangered Species) Ordinance both cover the terrestrial and aquatic organisms, including marine organisms. These cover the collection, possession and trade of endangered and rare species – especially those restricted under CITES. The Environmental Impact Assessment (EIA) Ordinance covers fisheries and ecological impacts. Coral communities are considered always as sensitive receivers, and these EIA reports are a good source of information on unexpected coral communities near major project developments. The most important legislation is the Marine Parks Ordinance enacted in 1995, which provides for the designation, control and

management of marine parks and marine reserves under the Country and Marine Parks Authority of the Agriculture and Fisheries Department (now the Agriculture, Fisheries and Conservation Department). The Authority is advised by the Country and Marine Parks Board with representatives from government departments, academia, NGOs and the public. Coral communities are very often the main focus for protection in the designation of marine parks and marine reserves.

### **Taiwan**

Coastal resources are protected under the National Park Law and the Coastal Environmental Protection Plan, which are administered by the National Park Department. However, these laws are not adequate to protect coastal areas. The Coastal Area Protection Act, which is focused on conservation and sustainable management, is under revision by legislators. This law may provide a better legal basis for the management of coastal areas in Taiwan.

### **Korea**

Principal acts and regulations affecting corals in Jeju Island and protected area are as follows: National Land Planning and Utilization Act;

- Public Waters Reclamation Act;
- Coast Management Act;
- Conservation of Wetlands Act;
- Prevention of Marine Pollution Act;
- Public Waters Management Act;
- Framework Act on Marine Fishery Development;
- Natural Parks Act;
- Protection of Cultural Properties Act;
- Natural Environment Conservation Act; and
- Special Act on Jeju Free International City

### **Japan**

There are several laws and ordinances to protect coral reef ecosystems in Japan. The Natural Parks Law and Nature Conservation Law protect certain areas which have significant natural features including corals and coral reefs. The Law for Conservation of Endangered Species regulates the capture and trade of rare species specified by Cabinet order. Fisheries Law and the Law for Conservation of Aquatic Resources are national laws, which prohibit coral harvesting. Prefectural governments also regulate the collection of corals in Okinawa and Ogasawara. To prevent soil runoff to coral reef areas, Okinawa Prefecture has the Red Soil Erosion Prevention Ordinance. Kagoshima Prefecture established the 'Amami Region Red-clay Outflow Prevention Measures Promotion Conference' to prevent red-soil runoff from public construction works in 2000 and developed a guideline, the 'Oshima Branch Office Strategy for Soil Runoff Countermeasures'.

### **Conservation Program**

#### **China**

The program 'Restoration of Coral Reef Ecosystem and Protection and Management of its Biodiversity in South China Sea of China' has been made a priority program of the 21<sup>st</sup> Century Ocean Agenda of China. A coral reef transplantation experiment was conducted in the Daya Bay in 2003 (because of a large scale Shell petrochemical project) and in the Luhuitou Sanya



in 1994. Reef Enhancement Units were deployed as alternative substrate for recruit settlement and coral fragment transplantation in Daya Bay in 2003.

### **Hong Kong**

The main marine conservation program in Hong Kong is working toward establishing a system of marine parks and reserves. The strict enforcement of EIA ordinance also helps to minimize destruction of coral communities from coastal development. Transplantation of coral colonies from the site of development has been considered as an alternative, but is not the preferred alternative to protect corals; on-site mitigation is always preferred. Recruitment enhancement experiments are being carried out to find a possible solution to the problem of site restoration; initial progress is encouraging.

### **Japan**

To counter the outbreaks of COTS, the Okinawa and Kagoshima Prefectures have conducted extermination programs in the Kerama Islands, Okinawa Island, Miyako Archipelago, Yaeyama Archipelago and Amami Archipelago, with assistance from local municipalities, fishermen and diving operators. Okinawa Prefecture has attempted to implement water quality control measures on Ishigaki Island to reduce the gradient of arable land, change the construction of drainage channels to filter out the red clay, and repair sedimentation ponds. Okinawa Prefecture and Ishigaki City have attempted to control runoff by constructing grit chambers and by decreasing the gradient of the fields, covering crops and mulching, planting sugar cane in spring, and developing green belts around the fields. In 1999, 38 administrative bodies and private organizations set up a conservation council for the sea around Ishigaki Island. This council attempts to prevent red soil runoff by planting sunflowers and other crops during the sugar cane fallow period, as well as a vegetation buffer around farmlands. The city of Hirara is promoting environmental conservation, fishery protection, and tourism, as part of a project to monitor the impacts of the annual Yabiji Reef landing tour in Miyako Islands. Volunteer reef guides have been introducing guidelines regulating tourism on this reef. The Zamami village fishery cooperative closed 3 diving sites in Kerama Island in 1998 to conserve corals, and mooring buoys were installed when the sites re-opened at Nishihama.

Reef restoration has been emphasised for coral reef conservation. New methods of restoration are being developed based on sexual reproduction of corals. Transplanting corals has also been conducted by volunteers and local fishers for enhancement and awareness; however, these have resulted in the parallel loss of some parent corals. Thus the Japanese Coral Reef Society and Okinawa Prefectural government are developing guidelines for these activities. A diving society was established in Kerama Islands in 2001 to develop a coral rescue program, with coral colonies removed from the east coast of Geruma Island adjacent to road construction, and transplanted to another island in 2002. Coral transplantation projects have been undertaken also in Tatsukushi Marine Park since 2000, with the aim of restoring the underwater scenery along a glass-bottom boat route. Similarly, coral transplantation projects have been ongoing since 2001 in the Uwa Sea Marine Park, to aid recovery of coral communities damaged by *Drupella* predation and a typhoon in 1993. Another transplantation project has been conducted by a volunteer organisation in the Shirigai Marine Park since 1999 to restore coral communities.

The Ministry of the Environment reviewed reef restoration practices in Japan and published a manual for reef restoration in 2004. The 'Law for the Promotion of Nature Restoration' was established in 2002, and aims to strengthen human coexistence with nature by preserving



biodiversity, and provides a framework for nature restoration by defining restoration as a joint effort among various actors/stakeholders. It is a first law to improve integrated management for environmental conservation. Nature Restoration Projects have been initiated by the Ministry, with 2 projects and 15 preliminary studies in operation in 2003. Two of these involved the restoration of coral reef ecosystems in Sekisei Lagoon in Okinawa Prefecture, and in Tatsukushi Bay in Kochi Prefecture.

## CONCLUSIONS AND RECOMMENDATIONS

### China

Coral reefs in China have faced many pressures and problems during the last 20 years, which to ensure they are rectified, now require special coordinating efforts from government, local communities and scientists. The major challenge for coral reef conservation and management is to balance the need of growing maritime economies (e.g. fishing, aquaculture and tourism) that use coral reef resources, with the need to protect and manage the reefs to sustain their value. Therefore, there is a need by government and society to develop a subtle balance between short-term economic benefits and the long-term sustainable use of environmental and ecological resources; these are difficult and sensitive issues for government and society. More efforts should be taken to develop ecologically and socio-economically sound models for management, and for the effective education of people to the value of biological conservation. The future prospects for coral reefs in China should be better in the near future, however, the situation is changing rapidly and the results will depend on the efforts of the key partners in conservation.

### Hong Kong

Coral communities receive more attention and better protection than 10 years ago. The government, NGOs and academia are promoting public awareness on the importance of coral reef protection in Hong Kong and elsewhere. Hong Kong is the largest importer of live reef fish in the world. Hong Kong coral communities continue to face enormous threats from development and ignorance, emphasising the need for more public education.

Long-term monitoring is needed for continuous evaluation of the health of coral communities, especially in MPAs. More comprehensive monitoring is also required for other organisms, e.g. fishes and algae, as well as the dominant corals. Better management of MPAs is needed including:

1. designation of no-take (core) areas in marine parks;
2. establishing monitoring stations and permanent transects and quadrats to evaluate coral growth and stresses on corals;
3. better management of tourist activities in MPAs, and provision of alternative livelihoods for fishers;
4. better enforcement of ordinances against poachers and illegal fishers;
5. reducing fishing efforts in and out of marine parks, providing alternative livelihoods for fishers; and
6. better and more effective public education campaigns and involvement of citizens in management of MPAs.

### Korea

There is considerable confusion because of overlapping control of protected areas and regional development plans, including the involvement of local stakeholders. Legislation at local and

national levels needs integrated and complementary coordination for effective management. Moreover, all stakeholders must be made aware of the importance of protecting the marine resources and socio-economic values of the ecosystems for the benefit of local communities. Sustainable fishing and tourism, as well as environmental education, are required. However the critical ecological, biological and socio-economic issues have not been identified, even though many surveys have been conducted in these areas. There is, therefore, a great need for long-term research and monitoring programs focused on coral ecosystems. A network of MPAs is required for effective management and conservation of the resources through sharing information and experiences. Currently, different departments and local governments in Korea manage the protected areas. A collaborative network of East Asian countries will significantly assist national efforts into research and monitoring, biogeography of corals and coral communities, alien species introductions, including temporary introductions carried by currents, and solutions for major environmental threats to coral species and their habitats.

### **Japan**

During the 10<sup>th</sup> International Coral Reef Symposium in Okinawa, all participants agreed to the 'Okinawa Declaration' (Box p 46) to reduce damage to coral reef ecosystems and enhance conservation and sustainable use of coral reefs. The Declaration included four key strategies:

1. achieve sustainable fishery on coral reefs;
2. increase effective marine protected areas on coral reefs;
3. ameliorate land-use change impacts; and
4. develop technology for coral reef restoration.

Such efforts must be fostered and sustained through stewardship and cooperation among scientists, managers, policymakers, non-governmental organisations, and the general public. Under the Declaration, there are recommendations to counter current issues on coral reefs, such as:

1. implementation of mechanisms to manage coral reef and COTS is required in areas that are likely to be threatened by COTS outbreaks in the future;
2. prevention of soil runoff to protect and maintain the production and recovery of coral reefs;
3. involvement of an integrated management approach by national and local governments for coral reef conservation, as a most effective mechanism is to involve local communities in integrated management activities;
4. developing and implementing region-wide monitoring programs is essential to understand regional patterns of water current effects and problems on coral ecosystems in each region of Japan and with other upstream coral reefs. These should be part of a national and global network for coral reef monitoring; and
5. continuous contributions to the international community are necessary to strengthen national activities and obtain benefits from the exchange of information and shared learning.

### **Taiwan**

There has been no improvement in the status of coral reefs in Taiwan in the past 2 years. Most of the reefs remain in a similar condition to that reported in 2000 and 2002, although some are continuing to degrade gradually. The growing demands of coastal development and tourism are putting the reefs in Taiwan under increasing human pressures. The task of managing both coral reefs and people in Taiwan, will involve tackling the degradation of coral reefs from over-fishing, sedimentation, sewage pollution, and recreational activities. Establishing MPAs with effective

law enforcement, prevention of marine pollution, restoration of corals and endangered marine organisms are crucial to the future of coral reefs in Taiwan. Effective laws for protecting the marine environment and resources are needed and more research activities on the population and community dynamics of reef organisms, physiological acclimation of corals, the impacts of climate change on coral reefs, and the techniques for restoring coral reefs are needed. Also, more educational activities to promote public awareness are required.

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