

**GCRMN**  
GLOBAL CORAL REEF  
MONITORING NETWORK

**STATUS OF  
CORAL REEFS  
OF THE WORLD:  
2008**

EDITED BY CLIVE WILKINSON



**Dedication:** This book is dedicated to all those people who are working to conserve the coral reefs of the world, either through doing the monitoring or providing the logistical and financial support – we thank them for their efforts. Special thanks to those people who wrote and edited these chapters. It is also dedicated to the International Coral Reef Initiative and partners, especially the Government of the United States operating through the US Coral Reef Task Force for support for the GCRMN by the US Department of State and the US National Oceanographic and Atmospheric Administration.

**Note:** The conclusions and recommendations of this book are solely the opinions of the authors, contributors and editors and do not constitute a statement of policy, decision, or position on behalf of the participating organisations, included those represented on the cover.

**Front Cover:**

This photo encapsulates the world of coral reefs, in this case in Micronesia where these three boys will be bequeathed damaged coral reefs. The large blue-green humphead or Napoleon wrasse (*Cheilinus undulatus*) is now listed as endangered on Appendix II of CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora), mainly because it is highly prized in Chinese restaurants: photo courtesy of Darren Cameron.

**Back Cover:**

This is a typical healthy coral reef, in this case Rowley Shoals Marine Park, Western Australia. The corals are abundant and healthy, and there are large schools of algal grazing fish, especially parrotfish and surgeonfish. No your eyes are not deceiving you, there is also a 'tropical' polar bear (explanation on page 13). The photo © Suzanne Long/Western Australian Department of Environment and Conservation.

Maps were provided by UNEP-WCMC through ReefBase, The WorldFish Center; we thank them.

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## FOREWORD

The International Coral Reef Initiative (ICRI) was conceived at the UN Conference on the Sustainable Development of Small Island Developing States in Barbados in 1994 in recognition of the problems facing coral reefs. As the Australian Ambassador for the Environment, I was pleased to Chair the negotiations that initiated ICRI and again in 1995 in Dumaguete City, Philippines when I Chaired the first ICRI General Meeting that recommended the formation of the Global Coral Reef Monitoring Network. ICRI has declared this year, 2008, as the ***International Year of the Reef*** to emphasise the need for urgent action to conserve coral reefs and the associated benefits they bring to people through their rich biodiversity resources. The first GCRMN global status report was produced in 1998, as massive climate change-related coral bleaching was devastating reefs in the Indian Ocean, Western Pacific and Wider Caribbean. We are pleased to report that many remote reefs in the Indian Ocean and Western Pacific, including Indonesian and Palauan reefs, are now recovering rapidly; however many other reefs facing heavy human pressures are recovering slowly or not at all. The world's coral reefs suffered two major setbacks since 2004: the Indian Ocean earthquake and resultant tsunamis in 2004 caused significant coral reef damage, especially in Indonesia; and 2005 was the hottest year on record throughout large parts of the Caribbean, resulting in extensive coral bleaching and mortality. Some Challenge countries lost more than half of their corals due to bleaching and disease. These events are documented for decision-makers in previous GCRMN reports.

We have joined our neighbouring leaders to launch two major challenges aimed at conserving coral reefs and their biodiversity: the Micronesia Challenge; and the Caribbean Challenge. This process started with the United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro in 1992, when world leaders signed Chapter 17 of Agenda 21, ratified the Convention on Biological Diversity (CBD) and pledged to conserve coral reefs.

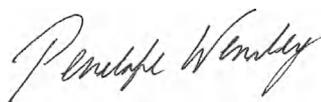
These pledges were essentially repeated at the World Summit on Sustainable Development in Johannesburg in 2002, and a 'challenge' was made within the CBD to significantly reduce the rate of global biodiversity loss by 2010. We responded to that challenge by launching our own regional challenges and also welcome three major marine protected area developments: the Papahānaumokuākea Marine National Monument near Hawai'i, the Phoenix Islands Protected Area of Kiribati, and the UNESCO World Heritage listing of many reefs in New Caledonia (see boxes pages 224, 195 and 184). The first major output was the Coral Triangle Initiative that includes Indonesia, Philippines, Malaysia, Papua New Guinea, the Solomon Islands and Timor Leste in a partnership to conserve their coral reefs and other marine resources. This was signed at the Asia Pacific Economic Cooperation (APEC) meeting in September 2007 in Australia with the support of other leaders attending (page 55).

Micronesia is immediately adjacent to the Coral Triangle and contains large areas of exceptionally rich biodiversity; but with lower human pressures. The value of this biodiversity is evident to all, including us in Palau. Therefore, as President of Palau, I asked my fellow leaders in the Federated States of Micronesia, Marshall Islands, Guam and Northern Mariana Islands

to take up the challenging target of conserving 30% of our marine resources and 20% of lands and forests by 2020. We launched the Micronesia Challenge in 2006 at the CBD meeting in Brazil, and are now putting words into action to meet this challenge with financial help from the Global Environment Facility, major NGOs, especially The Nature Conservancy and Conservation International, and pledges from various donor countries (page 48).

Caribbean island countries have also responded to the call to conserve their coral reef biodiversity. As Prime Minister of The Bahamas, I was pleased to confirm that the Dominican Republic, Jamaica, Grenada, and St. Vincent and the Grenadines joined the Caribbean Challenge at the 9th Meeting of the Conference of Parties to the CBD in Germany in May 2008. By adopting this challenge, we are committing to protect a minimum of 10% of our marine areas by 2012. Our small island states are very dependent on coral reef resources for both food and tourism income, and without major efforts by our peoples, assisted by international supporters, our reefs will continue to decline. To secure our livelihoods and our reefs we hope other Caribbean countries will also join the Challenge. These regional challenges and international cooperation are supported by the Global Island Partnership (GLISPA), which mobilizes the leadership of island nations and nations with islands to share resources, skills, knowledge and technologies towards action to conserve island resources and sustain livelihoods (page 280).

We are pleased to endorse this *Status of Coral Reefs of the World: 2008* report and the recommendations made by 372 people from around the world to conserve their coral reefs. Similarly, we reaffirm our support for the calls made at the World Summits in Rio de Janeiro in 1992 and Johannesburg in 2002, and through our challenges we ask the world to join us in conserving the world's coral reefs for the future and our children. We must act globally and locally to reduce the pressure humans place on coral reefs through pollution, increased sedimentation, excessive and destructive fishing practices, and mining or infilling of coral reefs. We must also combat global climate change as a new threat resulting in coral bleaching and increasing ocean acidification. And we must work with the people who live near coral reefs and depend on them for food and shelter to ensure they have sustainable and healthy livelihoods.



Penelope Wensley AO  
Governor of Queensland, and former Australian Ambassador for the Environment



Tommy E. Remengesau  
President of Palau



Hubert Alexander Ingraham  
Prime Minister of the Commonwealth of The Bahamas

## INTRODUCTION

This *Status of Coral Reefs of the World: 2008* report is the 5<sup>th</sup> global report since the GCRMN (Global Coral Reef Monitoring Network), was formed in 1996 as an operational network of the International Coral Reef Initiative (ICRI). The catalyst for GCRMN was the inability of international agencies to report objectively on the health or otherwise of the world's coral reefs. The US government then provided initial funding to set up a global network of coral reef workers to facilitate reporting on reef status; and has continued to be the major supporter of GCRMN and ICRI since the first strategies and action plans were developed in 1995. Each report (1998, 2000, 2002 and 2004) has aimed to present the current status of the world's coral reefs, the threats to the reefs, and the initiatives being undertaken under the umbrella of ICRI to arrest the decline in the world's coral reefs. These reports have been produced using the data and information from many coral reef experts around the world. For example 372 experts from 96 countries have contributed to this Status report. Many regional, national and local organisations, governmental, academic, NGO and volunteers have supported the functions of GCRMN. The united goal is to inform the global community on the status of coral reefs, the threats to them and, importantly, to list recommendations to improve coral reef conservation. There is widespread recognition that action is needed urgently, not only to conserve the enormous biodiversity on coral reefs, but also to assist local user communities to improve their livelihoods by ensuring the sustainable use of the reefs.

The Management Group of GCRMN have supported the production of *Status of Coral Reefs of the World: 2008*, although the GCRMN Coordinator, Clive Wilkinson, assumes responsibility for many of the statements, conclusions and recommendations and final wording of the text. The Management Group consists of the following international agencies: Intergovernmental Oceanographic Commission of UNESCO; UNEP – United Nations Environment Programme; IUCN – International Union for Conservation of Nature (and Management Group Chair); Environment Department of the World Bank; Convention on Biological Diversity; ReefBase at The WorldFish Center; Great Barrier Reef Marine Park Authority of Australia; and the Secretariat of the International Coral Reef Initiative (currently the governments of Mexico and US). Much of the strength of the GCRMN is through the partner networks, specifically GCRMN SocMon (Socioeconomic Monitoring Initiative for Coastal Management), the Reef Check Foundation, CRISP – the Coral Reef Initiatives for the Pacific, CORDIO – Coastal Oceans Research and Development, Indian Ocean, and the Reef and Rainforest Research Centre in northern Australia which hosts the global coordination office. These organisations represent thousands of people with the goal of improving research, management, sustainable use and conservation of coral reefs and associated tropical coastal ecosystems, and in assisting coastal people achieve a better standard of life.

The structure of this Status 2008 report follows previous reports in having 17 node chapters from coral reef regions around the world, with most of the contributions coming voluntarily from people coordinating and associated with these nodes. Also included are an update on cold water coral reefs and two theme papers presenting the latest information on global climate change and how this will affect coral reefs. We have also included a section on new emerging themes and reports from the major project activities around the world; others are to be found as boxes within the regional chapters. The GCRMN Management Group and the many supporters of the GCRMN listed below recommend this Status 2008 report to you and request that you consider the findings and recommendations and join them in seeking more action to reverse the damaging trends that are occurring on reefs around the world.

## ACKNOWLEDGEMENTS

Production of this book was only possible through the voluntary contributions of many people who are working to monitor, manage and conserve the world's coral reefs. We specifically thank them for their generous offer of data, information and time in monitoring reefs, analysing the data, writing these reports, assisting in the editing and proof reading and specifically in reviewing the regional chapters, often at very short notice. This Status 2008 report is presented in 2 formats: this published summary book; and the accompanying CD on which we include much more information and many more references to scientific papers and reports. This report will be lodged on ReefBase, at WorldFish Center, ReefBase Pacific in Fiji which act as the global and Pacific regional coral reef databases, [www.reefbase.org](http://www.reefbase.org) and [www.pacific.reefbase.org](http://www.pacific.reefbase.org). We wish to thank the reviewers of text for their effort and patience: Rich Aronson, Chris Bartlett, Charles Birkeland, John Bruno, Aude Caromel, Chou Loke Ming, James Crabbe, Leo Dutra, Moustafa Fouda, David Fisk, Alan Friedlander, Edgardo Gomez, Alison Green, Alain de Grissac, Virginie Tilot de Grissac, Stefan Hain, Andrew Harvey, Marea Hatzioolos, Scott Heron, Gregor Hodgson, Les Kaufmann, Mai-Britt Knopff, Judy Lang, Olof Linden, Christy Loper, Jim Maragos, Paul Marshall, Jaun Mate, Tim McClanahan, David Medio, Nyawira Muthiga, David Obura, Jamie Oliver, Russell Reichelt, Chris Roelfsma, Bernard Salvat, Mike Schleyer Charles Sheppard, Posa Skelton, Chris Simpson, David Souter, Robin South, Bob Steneck, Jerker Tamelander, Oliver Taylor, Karenne Tun, Alessandra Vanzella-Khourri, Ernesto Weil, Simon Wilson, Liz Wood. We specifically thank Kim Pritchard, Fiona Alongi, Florence Damiens and Heather Laurie for gathering information, formatting, editing and organising this complex task. Three operational partners of the GCRMN have assisted with this report: Gregor Hodgson and Jenny Mihaly of the Reef Check Foundation; Christy Loper of NOAA who coordinates the Socioeconomic Monitoring Network; Eric Clua who coordinates CRISP, Jerker Tamelander and David Obura, who coordinate CORDIO, and many other colleagues. The Management Group listed below provide substantial assistance, advice and support - we thank them all. The host of the GCRMN, the Reef and Rainforest Research Centre is specifically thanked. Support for the GCRMN primarily comes from the US Department of State, the National Oceanic and Atmospheric Administration via the offices of UNEP in Cambridge and Nairobi. Without this support there would be no GCRMN and this book; thus special thanks go my colleagues in these agencies. Funds to produce, print and distribute this book and distribute it free around the world came from: the Government of the USA (Department of State and NOAA); the Intergovernmental Oceanographic Commission of UNESCO; Great Barrier Reef Marine Park Authority; the United Nations Environment Programme (UNEP); IFRECOR – the French Government coral reef initiative; IUCN - International Union for Conservation of Nature; Project AWARE; RRRC - Reef and Rainforest Research Centre; and the Government of Japan. We offer a special thanks to NOAA for developing and maintaining coral-list; this amazing tool has kept coral reef workers connected and informed, and is a source of excellent information and lively debate. Special thanks go to Jim Hendee and his team at NOAA for their hard work and patience in assisting and keeping us under control.

| <b>GCRMN Management Group <sup>(1)</sup> Major Financial Supporters <sup>(2)</sup>, and Supporters of this report <sup>(3)</sup></b> |   |
|--|---|
| IOC-UNESCO: Intergovernmental Oceanographic Commission of UNESCO <sup>(1,3)</sup>  | GBRMPA: Great Barrier Reef Marine Park Authority <sup>(1,3)</sup>                 |
| UNEP: United Nations Environment Programme <sup>(1,2)</sup>  | WorldFish Center and ReefBase <sup>(1)</sup>                                      |
| IUCN: International Union for Conservation of Nature (Chair) <sup>(1,3)</sup>  | ICRI Secretariat: Governments of USA and Mexico <sup>(1)</sup>                    |
| The World Bank, Environment Department <sup>(1)</sup>  | RRRC: Reef and Rainforest Research Centre, Ltd (Australia), host <sup>(1,3)</sup> |
| CBD: Convention on Biological Diversity <sup>(1)</sup>   | The Environment Department, Government of Japan <sup>(3)</sup>                    |
| The Government of the USA, through the US Department of State <sup>(2)</sup>   |   |
| NOAA: National Oceanic and Atmospheric Administration, US Fish and Wildlife Foundation <sup>(2)</sup>                                |   |
| <b>GCRMN Operational Partners</b>  |   |
| GCRMN SocMon (Socioeconomic Monitoring Initiative for Coastal Management) at NOAA  | CORDIO: Coastal Oceans Research and Development, Indian Ocean.                    |
| Reef Check Foundation, Los Angeles   | IFRECOR: the French Government coral reef initiative <sup>(3)</sup>               |
| ReefBase, WorldFish Center, Penang; & ReefBase Pacific in Fiji   | Project AWARE in Los Angeles, London and Sydney <sup>(3)</sup>                    |
| World Resources Institute, Washington, DC  | CRISP - Coral Reef InitiativeS for the Pacific                                    |
|  | GCRMN Scientific and Technical Advisory Committee.                                |

# EXECUTIVE SUMMARY

CLIVE WILKINSON

## SYNOPSIS

Coral reefs of the world have effectively marked time since the last report in 2004. Some areas have recovered well after the climate change bleaching in 1998 and human damage; while the Indian Ocean tsunami, more bleaching in the Caribbean, and human pressures have slowed or reversed recovery.

Estimates assembled through the expert opinions of 372 coral reef scientists and managers from 96 countries are that the world has effectively lost 19% of the original area of coral reefs; 15% are seriously threatened with loss within the next 10–20 years; and 20% are under threat of loss in 20–40 years. The latter two estimates have been made under a 'business as usual' scenario that does not consider the looming threats posed by global climate change or that effective future management may conserve more coral reefs. However, 46% of the world's reefs are regarded as being relatively healthy and not under any immediate threats of destruction, except for the 'currently unpredictable' global climate threat. These predictions carry many caveats, as explained below.

In 2008, the International Year of the Reef, there is a mixture of good and bad news in this *Status of Coral Reefs of the World: 2008* report. Several major events have damaged coral reefs since December 2004 when the previous '*Status 2004*' report was released. But there have also been major positive steps taken to conserve the world's coral reefs. Some steps have been forward and some steps backward. Significant backward steps were:

- The Indian Ocean megathrust earthquake and tsunami struck on 26 December 2004 with enormous loss of life and disruption to Indian Ocean countries. There was considerable damage to the coral reefs of the Indian Ocean, but not at a scale comparable to human losses (Box p. 130);
- 2005 was the hottest year in the Northern Hemisphere since 1998 and this resulted in massive coral bleaching and hurricanes throughout the wider Caribbean in 2005 killing many corals and further damaging their reefs;
- Degradation of coral reefs near major centres of population continues with losses of coral cover, fish populations and probably biodiversity. This is certainly happening around the 'Coral Triangle', the world's centre for marine biodiversity (p. 55);
- There is increasing evidence that global climate change is having direct impacts on more and more coral reefs with clear evidence that rising ocean acidification will cause greater damage into the future;
- Socioeconomic assessments are increasing on coral reefs and being used more in management decision making. These assessments are being employed to strengthen or re-invigorate traditional management structures, especially in the Pacific where many traditional management regimes remain intact;

- However, coral reef declines will have alarming consequences for approximately 500 million people who depend on coral reefs for food, coastal protection, building materials and income from tourism. This includes 30 million who are virtually totally dependent on coral reefs for their livelihoods or for the land they live on (atolls);
- Problems for coral reef managers are increasing, as 50% the world's population will live along coasts by 2015, putting unsustainable pressures on coastal resources. The reefs they manage will contain less attractive but tougher corals. Rising food and fuel prices, commercialisation of fishing activities and the global financial crisis are resulting in over-fishing and serial depletion of fish stocks in many poor countries; and
- The solution remains in establishing more Marine Protected Areas linked into networks and managed by all stakeholders, especially user communities.

Countering such gloomy news, are some major advances:

- Two enormous marine protected areas (MPAs) focussed on coral reefs have been declared in the Pacific; the Papahānaumokuākea Marine National Monument covering the North-west Hawaiian Islands and the Phoenix Islands Protected Area (PIPA) were declared by the governments of USA and Kiribati respectively (Boxes p. 224, 195);
- Large areas of the coral reefs around New Caledonia have been given World Heritage listing (Box p. 184), and more areas are under consideration elsewhere;
- Coral reefs in the Indian Ocean, especially in the Seychelles, Chagos and the Maldives, and Palau in the Western Pacific, have continued to recover from the devastating bleaching of 1998;
- In December 2007 President Yudhoyono of Indonesia gained support and funding from world leaders for the 'Coral Triangle Initiative' to conserve the coral reef resources of Southeast Asia (p. 55);
- This initiative theme was expanded to include Western Pacific countries that border the Coral Triangle when President Remengesau of Palau instigated the Micronesia Challenge with other leaders who made commitments to conserve 20% of the land and 30% of the waters as protected areas in linked networks (p. 48);
- Soon after, Prime Minister Ingraham of The Bahamas gathered 4 of his neighbours to form the Caribbean Challenge that seeks to conserve 30% of their coastal resources (Box p. 280);

In addition, there have been other positive activities for coral reefs including:

- The International Coral Reef Initiative, currently co-chaired by Mexico and the USA, declared 2008 as the International Year of the Reef and developed major awareness raising campaigns around the world;
- The 11<sup>th</sup> International Coral Reef Symposium assembled 3500 scientists, managers and decision makers in Ft Lauderdale, USA, in July 2008 to bring the power of science to coral reef conservation (p. 43);
- Reef Check has organised 20 700 signatures on the 'Declaration of Reef Rights' petition launched in the International Year of the Reef;
- The Pew Environment Group is working with developed country governments to declare very large areas as no-take marine reserves, including the Coral Sea of Australia, the Northern Mariana Islands, the Chagos Archipelago in the Indian Ocean, and the Kermadec Trench, off New Zealand;

- The Coral Reef Targeted Research and Capacity Building for Management Program established 4 Centres of Excellence to build science capacity for management (p. 47)
- CRISP (Coral Reefs InitiativeS for the Pacific) has expanded operations into 17 Pacific island countries with considerable progress in raising capacity for reef management and socioeconomic assessment (p. 45 )
- The French and USA governments completed major national coral reef summary reports in 2008; the South West Pacific Node produced a regional report in 2007: the French and SW Pacific Node reports were presented in GCRMN format;
- The Global Environment Facility has allocated \$100 million as the Pacific Alliance for Sustainability to bring Pacific countries together to conserve their environments. Part of this money is going towards the Coral Triangle Initiative and the Micronesia Challenge;
- Germany has launched a new Biodiversity and Climate Research Centre based at the Senckenberg Research Institute in Frankfurt; it will have a significant coral reef component.

A series of Recommendations are listed below.

## THE EXECUTIVE SUMMARY: THE STATUS OF CORAL REEFS IN 2008

This *Status of Coral Reefs of the World: 2008* report from the Global Coral Reef Monitoring Network summarises what has happened to the world's coral reefs since 2004 and uses expert opinion of coral reef scientists and managers from 96 countries and states to make predictions on what could happen to coral reefs in the future. This combined expertise also seeks to provide advice to the world's decision makers on what should be done to allow us to bequeath healthy coral reefs to future generations. The release of this report coincides with the end of the International Year of the Reef (IYOR 2008), which has focussed considerable global attention on coral reefs.

One of the signs of progress in coral reef awareness and monitoring are the numbers of authors and contributors to these Status reports. There were 41 contributing authors in 1998; 97 in 2000; 151 in 2002; and 240 in 2004. In this Status 2008 report there are 372 authors and contributors. These numbers also reflect considerable advances in monitoring in many countries of the world, with some long-term data sets being contributed and reports coming in from countries not reported previously — Timor Leste, island states of the Lesser Antilles and isolated French Islands.

## RECOMMENDATIONS FOR ACTION TO CONSERVE CORAL REEFS

These summary recommendations are based on the 17 regional chapters and the other specialist reports. There are more detailed and specific recommendations at the end of most chapters: these are considered the most urgent by the many authors and contributors to conserve coral reefs for future generations:

- **Urgently combat global climate change**— current rates of climate change pose the greatest threat to the long-term sustainability of coral reefs and human coastal communities. We request that the world community, through their governments, agencies, NGOs, academic institutions and especially business establishments, collaborate to urgently reduce the current rate of emissions of greenhouse gases through reductions in energy use and the development of sustainable energy generating mechanisms or trading systems, and develop technologies to remove these gases, especially CO<sub>2</sub>, from the atmosphere, to ensure that coral reefs will thrive in the next century.
- **Maximise coral reef resilience** (by minimising direct human pressures on reefs) – the

second major threat to reefs derives from direct human activities: over-fishing and destructive fishing; sediment pollution from poor land use; runoff of nutrients and other pollution; and habitat loss through unsustainable development. Control of these threats, which are damaging reefs around the world especially in developing countries including small island developing states, will improve the resilience of coral reefs in the face of climate change. These countries need assistance to improve local catchment and coastal management by upgrading capacity and providing funds to implement community-based management and develop alternative livelihoods to take pressures off reefs.

- **Scale up management of protected areas** – there is a need to improve the management of existing marine protected areas (MPAs) to accelerate restoration of depleted fish stocks and protect coral reef goods and services that underpin coastal economies and livelihoods. This includes managing adjacent catchment areas to prevent nutrient and sediment pollution to create buffer areas that will reinforce MPA management activities.
- **Include more reefs in MPAs** – a proven and effective governance approach for conserving coral reefs and promoting sustainable use is to include them in effectively managed MPAs; preferably containing a significant proportion as fishery reserves or no-take areas, linked into a network of MPAs, and embedded within a larger governance framework. Developing countries will need assistance in expanding their MPA networks and establishing integrated coastal management (ICM) governance frameworks.
- **Protect remote reefs** – there are many coral reefs remote from continental land masses and human populations that, if they are protected, will be able to act as reservoirs of biodiversity to replenish depleted reefs. We recommend establishing more MPAs to include many of the remote island reefs, like those to the west of Hawai'i, in Kiribati, and the Coral Sea east of the Great Barrier Reef. Developed countries may have the best resources in governance and enforcement to conserve large remote areas in their territorial waters.
- **Improve enforcement of MPA regulations** – enforceable governance systems will be required to deal with the formidable problem of regulating access to managed ecosystems (including types and rates of resource exploitation). Many countries will need assistance to establish effective enforcement systems that function in different marine coastal and marine environments and do not undermine local cultural values and practices.
- **Help improve decision making with better ecological and socioeconomic monitoring** – there is an urgent need to upscale monitoring, especially with increasing threats of climate change, to ensure that this information is provided to natural resource managers and decision makers so that appropriate actions can be taken to reduce threats to reefs and coastal communities.

## STATUS NOW AND PREDICTIONS FOR THE FUTURE

The GCRMN has used the reports from 372 authors and contributors to assess the current status of the world's coral reefs and make predictions about the future of reefs out to 40 years from now. There are contrasting trends: reefs are recovering from the massive bleaching losses in 1998 in the Indian Ocean and Western Pacific; however, there were similar scale bleaching losses in the wider Caribbean in 2005 and 2006; direct human pressures are resulting in chronic losses on coral reefs near major population centres; while effective coral reef management is reducing threats in a number of countries.

**Reefs Effectively Lost:** Expert opinion backed by extensive monitoring and assessment data suggest that the world has lost the goods and services provided by 19% of the global coral reef area. These

reefs are either so heavily degraded as to be non-functional, or have been polluted or mined out of existence. The comparable figure was 20% in 2004. The decrease of 1% is due to strong coral reef recovery particularly in the Indian Ocean and Western Pacific after the devastating bleaching in 1998. However, recovery is stalled or weak where there are substantial human pressures (over-fishing, pollution, sedimentation and unwise development). Countering that, there were major losses in the wider Caribbean following similarly devastating bleaching, coral diseases and hurricanes in 2005, compounded by on-going degradation from sediment and nutrient pollution and over-fishing and associated damage. Reefs in the heavily populated areas of Asia and the wider Caribbean report most losses. Reefs in the Persian Gulf have been devastated by major coral bleaching events and recently by extensive coastal developments along the Arabian Peninsula. Many reefs in this category are not irretrievably lost and will recover if human stresses can be reduced or if the devastating impacts of coral bleaching, diseases and predators are not repeated in the short-term.

Predictions about the future of coral reefs are particularly difficult as multiple stresses and climate factors impinge on reefs. Thus, we recommend that these predictions be used as a guide, particularly for national, international and funding decision makers to establish priorities for action. These predictions are made on a 'business as usual' assumption that there will be no major improvements in remedial management action and not considering the looming threats posed by global climate change. This latter assumption effectively ignores the growing global consensus that climate change seriously threatens the medium to long-term future for the world's coral reefs.

**Reefs at the Critical Stage:** It is predicted that 15% of the world's coral reefs are under imminent threat of joining the 'Effectively Lost' category within the next 10–20 years, unless effective management actions are implemented. These predictions are based on observed trends over the past decade, on demographic increases in human population pressures, and assessments of the effectiveness of current management. The regions with most 'Critical Stage' reefs have not changed from 2004 (predominantly Eastern Africa, South and South-east Asia and the wider Caribbean), where human pressures are regarded as high and increasing in the regional chapters below. This is a decrease from the 2004 estimate of 24% critically threatened.

If current predictions from the Intergovernmental Panel on Climate Change and coral reef experts (see p. 29 & 35) are factored into these assessments, this category or the next (threatened) will contain all of the remaining coral reefs. This is why urgent action is needed to drastically reduce the emissions of greenhouse gases.

**Reefs at the Threatened Stage:** The predictions are that 20% of reefs are under threat of loss in 20–40 years; again with the caveat that management will be ineffective at reversing growing demographic pressures. The location of these 'Threatened' reefs is similar to the Critical Stage reefs, and includes those a little more remote from human disturbances or 'next in line' for serious exploitation of development. This is a decrease from the Threatened state in 2004 of 26%.

**Reefs at Low Risk:** Fortunately, the regional experts consider that 46% of the world's reefs are either stable or recovering rapidly and not threatened by significant levels of human stresses. Most of these reefs are either well managed such as the Great Barrier Reef, Bonaire, Bermuda, the Flower Garden Banks and Cuba, or remote from large land masses and human disturbances such as the Red Sea, the Maldives, Seychelles and Chagos in the Indian Ocean, and Papua New Guinea and many small atolls and islands in the Pacific Ocean, along with a few reefs in the wider Caribbean and Atlantic Ocean. The comparable figure was 30% in 2004, with the differences mainly being reefs that have recovered after the 1998 bleaching and the discovery of large areas of deeper reefs, especially in the Northern Caribbean.

**Caveats:** These status assessments and predictions are based on considerable monitoring data using a range of methods, varying from very detailed species level monitoring to rapid monitoring by trained volunteers (see p. 18). However, it is recognised that monitoring in many countries only covers a small and unrepresentative proportion of the reefs, such that the monitoring data are inadequate for a quantitative assessment. In these cases we have relied on qualitative assessments based on the expert opinion of national and visiting scientists, complemented by information from professional dive guides.

Reefs categorised as lost are not effectively functioning as coral reefs and exhibit many of these criteria: live coral cover has declined radically (to below 5%); many remaining corals are either broken, diseased or covered in sediment; fish populations are seriously over-fished with very few large predators and algal grazing fish; there is clear evidence of pollution with poor quality turbid water; and the reefs are being over-grown with macro-algae, sponges or other organisms favoured by polluted waters. Another caveat is that the predictions of 'Threatened' and 'Critical' are based predominantly on future human stresses, without considering the threats of global climate change, predicted to be inevitable but without clear timelines. We have assessed the validity of regional assessments in the Table on p.18).

## DAMAGING EVENTS FOR CORAL REEFS 2004 - 2008

Immediately after the Status 2004 report was launched in December 2004, the devastating Indian Ocean tsunami occurred; and 6 months later in 2005 catastrophic coral bleaching enveloped the wider Caribbean. In addition, the level of damaging human activities has continued to increase in parallel with increases in human populations, especially in the coastal tropics. These increases make the task for natural resource managers even more difficult and urgent.

**The Indian Ocean Earthquakes and Tsunamis of 2004:** The largest earthquake for 40 years struck near Sumatra on 26 December 2004 and spread 1300 km to the Andaman Islands of India. Some reefs in Sumatra and the Andaman Islands were thrust out of the water killing them almost instantly. The resulting tsunamis killed more than 230 000 people in Indonesia, Thailand, the Andaman and Nicobar Islands of India, and Sri Lanka, and devastated their lands and economies. There was significant damage to reefs in Indonesia, Thailand, the Andaman Islands and Nicobar Islands, Sri Lanka and the Maldives, with much of the damage caused by debris from the land or dead coral rubble smashing or smothering other corals. Most of the corals have since recovered but over-fishing and pollution from poor land use and inadequate treatment of wastes remain as major threats (*from Wilkinson C, Souter D, Goldberg J (2006). Status of Coral Reefs in Tsunami Affected Countries: 2005. Australian Institute of Marine Science and Global Coral Reef Monitoring Network, Townsville Australia, 154 p.*).

**Coral Bleaching and Hurricanes in the Caribbean in 2005:** 2005 and 1998 were the hottest, and most devastating, years for coral reefs since global records started in 1880. In 1998 the damage was greatest in the Indian Ocean, Western Pacific and the Caribbean. In 2005 the damage was confined to the wider Caribbean where coral bleaching and mortality compounded previous bleaching in 1987, 1995 and 1997–1998. Losses were extreme: 51.5% losses of live hard coral cover at sites in US Virgin Islands; more than 50% of coral colonies bleached in Florida, Puerto Rico, the Cayman Islands, St. Maarten, Saba, St. Eustatius, Guadeloupe, Martinique, St. Barthelemy, Barbados, Jamaica and Cuba; up to 20% coral mortality on Barbados; 11–30% mortality in the French West Indies, and Trinidad and Tobago. Also, 2005 was the most severe hurricane season ever with 26 tropical storms including 13 hurricanes, which damaged coral reefs (e.g. coral cover was halved around Cozumel, Mexico). Many stressed and bleached corals subsequently died from coral diseases in 2006 (*from Wilkinson C, Souter D, (2008). Status of Caribbean Coral Reefs after Bleaching and Hurricanes in 2005. Global Coral Reef Monitoring Network and Reef and Rainforest Research Centre, Townsville Australia 152 p.*).

| Region              | Coral Reef Area km <sup>2</sup> <sup>1</sup> | Effectively Lost Reefs (%) <sup>2</sup> | Reefs at Critical Stage (%) <sup>3</sup> | Reefs at Threatened Stage (%) <sup>4</sup> | Reefs at Low Threat level (%) <sup>5</sup> |
|---------------------|--|---|--|--|--|
| Red Sea             | 17 640                                       | 4                                       | 4  | 10   | 82   |
| The Gulfs           | 3800   | 70                                      | 15                                       | 12   | 3  |
| Eastern Africa      | 6800   | 15                                      | 22                                       | 28   | 35   |
| SW Indian Ocean     | 5270   | 9                                       | 24                                       | 39   | 29   |
| South Asia          | 19 210                                       | 25                                      | 20                                       | 25   | 30   |
| SE Asia             | 91 700                                       | 40                                      | 20                                       | 25   | 15   |
| E & N Asia          | 5400   | 20                                      | 22                                       | 18   | 40   |
| Australia, PNG      | 62 800                                       | 3                                       | 4  | 10   | 83   |
| SW Pacific Islands  | 27 060                                       | 4                                       | 17                                       | 35   | 44   |
| Polynesian Islands  | 6733   | 3                                       | 2  | 5  | 90   |
| Micronesian Islands | 12 700                                       | 8                                       | 7  | 15   | 70   |
| Hawaiian Islands    | 1180   | 2                                       | 4  | 8  | 86   |
| US Caribbean        | 3040   | 21                                      | 31                                       | 19   | 29   |
| North Caribbean     | 9800   | 12                                      | 13                                       | 30   | 45   |
| Central America     | 4630   | 14                                      | 24                                       | 22   | 40   |
| Lesser Antilles     | 1920   | 13                                      | 31                                       | 22   | 34   |
| S Tropical America  | 5120   | 13                                      | 40                                       | 17   | 30   |
| <b>TOTAL</b>        | <b>284 803</b>                               | <b>19</b>                               | <b>15</b>                                | <b>20</b>                                  | <b>45</b>                                  |

1. Coral reef area from the World Atlas of Coral Reefs (2001).

2. Reefs 'effectively lost' with 90% of the corals lost and unlikely to recover soon;

3. Reefs at a critical stage with 50 to 90% loss of corals and likely to join category 2 in 10 to 20 years;

4. Reefs threatened with moderate signs of damage: 20–50% loss of corals and likely to join category 1 in 20–40 years

5. Reefs under no immediate threat of significant losses (except for global climate change).

Categories 3 and 4 are based on the very high to high risk, and the medium risk categories of the Reefs at Risk process

*The table summarises the current status of the world's coral reefs determined from the regional chapters (below). These estimates were determined using considerable coral reef monitoring data, some anecdotal reports and the expert opinion of hundreds of people associated with the Global Coral Reef Monitoring Network (GCRMN). These assessments should be regarded as indicative, because there is insufficient coral reef monitoring data for many of these regions to make definitive statements on losses and authoritative predictions on the future.*

**Plagues and Diseases:** There are disturbing reports of new outbreaks of crown-of-thorns starfish (COTS) devastating coral reefs in the Red Sea around Egypt, along the coast of East Africa in Kenya and Tanzania, in parts of South-east and East Asia (especially in the Philippines, Japan and China), and in the Pacific in Guam, Majuro Atoll (Marshalls), Fiji and French Polynesia. In the past, these plagues have caused massive losses (often in the vicinity of 90%) of living coral cover. Similarly there are reports of outbreaks of the coral eating mollusc (*Drupella cornus*) on reefs in Western Australia and southern China.

Diseases devastated coral populations throughout the wider Caribbean in the 1980s and 1990s, particularly affecting *Acropora* species, and reducing coral cover significantly. After apparently abating, massive outbreaks of disease accompanied the mass coral bleaching in 2005 and 2006. The severity of these diseases is often correlated with corals stressed by bleaching, being most severe in summer and declining in winter. Coral diseases are being observed more frequently on Indo-Pacific reefs but are not nearly as serious as in the Caribbean.

**Continuing Human Stresses on Coral Reefs:** In the Status 2004 report, we listed the 'Top 10' threats to coral reefs under 3 categories. Sadly these continue in 2008 with no signs of abatement: **The 'Global Change Threats':** 1) coral bleaching from warmer seawater due to global climate change; 2) rising concentrations of dissolved CO<sub>2</sub>, also a product of climate change; 3) diseases, plagues and invasive species. **The 'Direct Human Pressures':** 4) excess sediments flowing off the land; 5) pollution by nutrients and chemicals, arising from poor land management, agriculture and industry; 6) over-fishing and destructive fishing, especially taking algal grazing fishes, the 'immune system' of a coral reef; 7) unsustainable and destructive development of coastal areas. **'Inadequate Governance, Awareness and Political Will':** 8) increasing poverty and populations, and loss of agricultural land; 9) poor capacity for management and lack of resources, especially in small island countries; and 10) weak political will, and ineffective oceans governance. The last 7 threats are amenable to local action, aided by donor and developed countries providing some financial and logistical resources. The first 3 threats can only be solved by unified and concerted global action by all governments and people; the Kyoto conference successor, in Copenhagen, December 2009 will determine whether the world is willing to take these necessary steps. The current fear is that the Global Financial Crisis of 2008 will provide an excuse for governments to avoid taking the necessary action in the short-term.

## MAJOR NEW INITIATIVES IN CORAL REEF CONSERVATION

By the start of the millennium there was increasing recognition that accelerated efforts were required to reverse loss of biodiversity and conserve ecosystems. In April 2002 the Convention on Biological Diversity pledged to significantly reduce the rate of biodiversity loss by 2010, as a contribution to poverty alleviation and to the benefit of all life on Earth. This target was endorsed by the 2002 World Summit on Sustainable Development (WSSD) in Johannesburg and the United Nations General Assembly, and was incorporated as a new target under the Millennium Development Goals. For coral reefs, the WSSD target of establishing networks of marine protected areas (MPAs) encompassing 20% of marine resources by 2012 was critical. We consider that these calls have positively stimulated more effective coral reef conservation.

**Coral Triangle Initiative:** Conservation of the world's highest biodiversity coral reefs is a target for Indonesia, Philippines, Malaysia, Papua New Guinea, the Solomon Islands and Timor Leste. They formed the Coral Triangle Initiative in 2006 in response to calls by the Convention on Biological Diversity and the WWF to reduce the loss of biodiversity and set up networks of MPAs. President Yudhoyono of Indonesia is marshalling international assistance to conserve the biodiversity, fisheries and food security potential of these vast marine resources surrounding thousands of islands with a current budget of \$300 million from governments, UN agencies and NGOs.

**The Micronesia Challenge:** This arose at the same time when Palau, Federated States of Micronesia, the Marshall Islands, Guam and the Northern Mariana Islands pledged to conserve at least 30% of their marine resources and 20% of terrestrial resources by 2020. They seek a budget of \$100 million to establish new MPAs and strengthen existing ones to conserve 61% of the world's coral species, more than 13 000 species of reef fishes, 85 species of birds, 1400 species of plants; all with considerable cultural significance.

**Caribbean Challenge:** Caribbean countries accepted the challenge from Micronesia to launch the Caribbean Challenge to conserve biodiversity. The Bahamas, Dominican Republic, Jamaica, Grenada, St. Vincent and the Grenadines have all pledged to conserve 20% of their marine and coastal habitats by 2020 because the livelihoods and cultures of 10 million people depend on these resources. Other countries are also considering joining. A key component will be the creation of a US\$45 million Trust Fund to fund rangers, patrol boats, scientific expertise and education programs in new and existing MPAs.

**New Large MPAs:** Two enormous MPAs in the Pacific were launched in 2006. The **Papahānaumokuākea Marine National Monument** was upgraded to highly protected status by the USA to take in the 356 893 km<sup>2</sup> of the Northwestern Hawaiian Islands Coral Reef Ecosystem Reserve, designated in 2000. The Government of Kiribati, with help from major NGOs, has created the world's largest marine protected area by enlarging the **Phoenix Islands Protected Area** (PIPA), in January 2008, to encompass 410 500 km<sup>2</sup>. These eclipse the Great Barrier Reef Marine Park, established in 1975 and upgraded in 2004, which has 115 395 km<sup>2</sup> as no-take status out of the total 344 400 km<sup>2</sup>. The Pew Environment Group has commenced a campaign to encourage developed country governments with adequate capacity and enforcement capability to declare very large ocean areas as no-take marine reserves. They have proposed the Coral Sea of Australia and then seek to include the Northern Mariana Islands, the Chagos Archipelago in the Indian Ocean, and the Kermadec Trench off New Zealand.

**World Heritage and Coral Reefs:** In June 2008, the World Heritage Commission listed 6 large areas of New Caledonia for special protection including 15 743 km<sup>2</sup> of coral reefs. They acknowledged that these reefs are of global significance with a large concentration of biodiversity resources. The Republic of the Marshall Islands intends seeking World Heritage recognition for 9 atolls and one low reef island in 2009, and the government of Thailand is investigating a similar proposal for large areas of the Andaman Sea coast with substantial coral reefs.

## **POLAR BEARS AND CORAL REEFS**

Putting polar bears and tropical corals into the same sentence is an unusual concept, possibly bizarre. But the linkage of the two charismatic animals, just one species of bear and more than 700 species of coral, encapsulates the position the world faces with global climate change. This dilemma for the world was brought home to me by Bill Eichbaum, a colleague working with WWF in Washington D.C.

Climate change threatens both the Arctic and tropical coral reefs; from 90° North to the tropics around 0°. These two extremes illustrate that climate change will have dramatic effects at the extremes of the world's ecosystems, and all ecosystems between them. The threats to these two charismatic animals should serve as warning that global climate change will probably devastate ecosystems across the whole latitude range from the tropics to the Poles. These changes could lead to the extinction of the polar bear *Ursus maritimus* and to the extinction of many of the 700 species of coral. Polar bears and corals are evolutionarily very different: polar bears are at the tip of one mammal branch; while corals still resemble the first 'modern' corals that evolved about 35 million years ago. But both the bears and corals have evolved spectacularly well into their current environments, such that they are now totally dependent on these environments. The changes wrought by global climate to alter those environments will threaten their existence and could result in extinction; just a few degrees of warming will be devastating. Kent Carpenter and 34 colleagues reported in *Science*, in July 2008, that one third of all tropical corals are considered as immediately threatened with extinction using IUCN Red List Criteria. The proportion of corals threatened with

extinction has increased dramatically in recent decades and exceeds most terrestrial groups. Neither bears nor tropical corals will go extinct immediately; we will still be able to see some in zoos and aquaria which will symbolise the losses of these animals in the natural environment. Unlike the photo on the back cover, polar bears will not migrate to coral reefs (that can only happen with 'Photoshop').

### **CONSEQUENCES OF GLOBAL CLIMATE CHANGE FOR CORAL REEFS**

The very serious threats posed by global climate change to coral reefs were confirmed when 3500 of the world's leading coral reef scientists and managers met at the 11<sup>th</sup> International Coral Reef Symposium in Florida, in July 2008. The news from these scientists was far from encouraging. Major consequences of increasing greenhouse gases will be:

- more coral bleaching from warmer oceans;
- rising ocean acidification from more dissolved carbon dioxide (CO<sub>2</sub>);
- more severe storms; and
- rising sea levels that will drown some coral reef nations.

Climate change is proceeding faster than in previous ice-age transitions and coral reefs and corals are falling behind and suffering fever-high temperatures and rising acidity. There are some hopeful signs, but no single, easy remedy.

Coral reefs may be the first marine ecosystem to suffer extreme damage and possible collapse from climate change. Two major, ocean-scale bleaching events hammered home the message that warming oceans associated with global climate change pose a major, and probably THE major threat to the future of coral reefs and their associated organisms around the world. The extreme El Niño/La Niña switches in the global climate in 1997–1998 resulted in the most extensive coral bleaching and mortality ever recorded, with approximately 16% of the world's coral reefs being effectively destroyed (approximately three quarters of these have subsequently recovered). Coral losses were greater than any in recorded history because 1000 year old corals were killed. And in 2005 many coral reefs of the wider Caribbean were devastated when a series of major 'hot-spots' developed during the northern summer of 2005. There was extensive coral bleaching (experts quoted in the regional chapters report more than 50% bleaching with half of these corals dead soon after or due to coral diseases striking the weakened corals in 2006); 2005 was a record hurricane year, which also resulted in considerable coral reef losses.

Since 1998, many coral reefs of the Indian Ocean and Western Pacific have shown remarkable recoveries in coral cover. For example, the Chagos Archipelago, some outer islands of Seychelles, the Maldives, Bar Reef on Sri Lanka, and Palau now have corals at levels approaching pre-1998 cover. The major questions are whether the 1998 and 2005 events were singular events or harbingers of more doom in the future. Sadly, the evidence and predictions from the Intergovernmental Panel on Climate Change 2007 report indicate that similar destructive events are certainly more probable as the world's climate heats up.

NOAA satellites reveal tropical oceans have warmed at a significantly faster rate during the last 10 years (see p. 35), suggesting that there are only 8–10 years left to turn the tide because, if atmospheric CO<sub>2</sub> concentrations reach 450 ppm, seawater will become more acidic, thereby threatening the existence of coral reefs as we know them. Healthy and resilient coral reefs can respond vigorously to damage; but climate change stresses are eroding that resilience. For example, ocean acidification will prevent juvenile corals settling and make adults more fragile (see p. 29).

## “YOU DON’T KNOW WHAT YOU GOT ‘TIL IT’S GONE”

These words from the classic 1970 song, ‘Big Yellow Taxi’ by Joni Mitchell, may describe the situation we find ourselves in now. In the past few years, coral reef scientists have reported that some animals, e.g. crinoids (feather stars) in the wider Caribbean, that were previously common on their coral reefs are now absent. Another report states that the abundant sea snakes on coral reefs off Western Australia have apparently disappeared. The loss of these animals off coral reefs may be an example of the miner’s canary, warning us of many more unintended consequences of global climate change.

There are convincing anecdotal reports that crinoids have ‘disappeared’ from many coral reefs in Florida, as Billy Causey reported in the GCRMN report on the bleaching in the Caribbean in 2005 (reference above). When diving began along the Florida reef tract in the 1960s and 1970s, many colourful crinoids were seen and photographed on shallow reef, like Looe Key Reef, and especially on deep reefs from 20–40 m. However, none were found during 6 hours of survey diving in 2001 on deep reefs at 20 m and 30 m. Repeat surveys have failed to find any crinoids, however, researchers still see crinoids in the Tortugas Ecological Reserve. Thus crinoids are still found on reefs well to the west of Florida, but not on the reefs directly offshore. Steve Gittings from NOAA has observed a major decline in ophiuroids (brittle stars) at Conch Reef in the Upper Florida Keys.

Similar evidence has come from Netherlands Antilles in the far south of the Caribbean. Dave Meyer reported at the 11<sup>th</sup> International Coral Reef Symposium that the previously abundant comatulid crinoids that flourished on Bonaire and Curaçao in the early 1990s were declining drastically by 1996 and that, in 2007, sites that once had many crinoids are now practically empty. Five species of crinoids were common in shallow waters and at least 2 species occurred down to 30 m depth. The reasons for the decline are unclear and were comparable on the lightly populated Bonaire to the more heavily populated Curaçao. Thus a finger is being pointed at the climate change associated bleaching in 1995: the loss of these major filter feeders raises new concerns and should stimulate surveys and monitoring of crinoids and other reef biota throughout the world. The question is asked: are multiple stressors like higher levels of nutrients and other pollutants from the land combining with warmer waters to cause these losses of feather and brittle stars? Are echinoderms the ocean equivalent of frogs, warning us of more extinctions to come?

Other animals may also be disappearing off reefs. The coral-like animal, *Ricordea florida* (a corallimorph, or called ‘false coral’), occurred in large patches on shallow reefs such as Looe Key Reef in the 1960s and 1970s. The first signs of loss were in the early 1980s with virtually none in the shallow waters when detailed and regular monitoring started in 1996.

There were at least 9 species of sea snakes in the shallow waters of a cluster of reefs that form Ashmore Reef in the Indian Ocean, about 800 km west of Darwin. These reefs sit on the edge of the continental shelf and sea snakes were recorded as ‘super abundant’ in previous surveys. For example, more than 400 specimens were collected in a week by the RV Alpha Helix in 1972. Mick Guinea reports that now sea snake numbers have so decreased that one sea snake may be seen per week. The reasons for the losses are unknown on Ashmore (but no losses on nearby Hibernia, Scott and Cartier reefs), but there are hypotheses: the channels have silted up and sand banks now cover many coral heads; sea surface temperatures are increasing (see p. 35); or over-exploitation of some species has also had a ‘downstream’ affect on the sea snakes, although fish populations appear healthy.

## STATUS OF CORAL REEFS OF THE WORLD BY REGIONS

### *Indian Ocean*

- **Persian Gulf, Arabian Sea and Gulf of Oman:** There has been minimal recovery in reefs of the Persian Gulf and Gulf of Oman after climate related devastation in 1996, 1998 and 2002, and massive cyclone 'Gonu' in mid 2007. Massive coastal development on the Arabian Peninsula side is also resulting in coral reef losses. These reefs appear amongst the most damaged in the world with the lowest predictions for recovery. Coral reef research and monitoring continues to lag behind other parts of the world, with Iran seeking to improve reef monitoring and management activities in the Node states;
- **Red Sea and Gulf of Aden:** The reefs continue to be in good health with gradual increases in reef awareness. There have been some localised losses from coral bleaching and crown-of-thorns starfish, but generally coral cover remains high to very high. Countries have developed action plans, however, there are major disparities in capacity and economics between relatively wealthy countries and those emerging from recent wars;
- **Eastern Africa:** Along the coastline there is a mix of reef recovery and reef degradation as management efforts are directed towards controlling the effects of rapidly growing populations and involving local communities in coastal management. All countries are increasing their networks of MPAs in line with the WSSD calls. Kenya and South Africa share the lead in monitoring activity, but all countries are improving management capacity and legislation;
- **Indian Ocean Islands:** Reefs in the south-west of the ocean continue to recover after devastation in 1998. Some reefs of the Seychelles and Comoros that suffered major damage in 1998 have probably regained about half the lost coral cover; there has also been virtually no recovery on others. There have been major advances in awareness and the declaration of new MPAs, but the problems confronting governments and communities with increasing development and populations continues to nullify positive activities. There has been a reduction in monitoring sites and the flow of information, and little is known on the status of seagrass and mangrove areas.
- **South Asia:** The poor situation in South Asia continues as a mix of reef decline as large human populations further damage the coral reefs, adding to damage that occurred in 1998; governments are increasing their efforts, but will they be too late? However, there has been amazing recovery of the reefs of the western Maldives, Chagos, Lakshadweep Islands of India and on north-west Sri Lanka, with seemingly locally extinct corals making major recoveries e.g. some reefs have gone from less than 5% coral cover to 70% in 10 years. The 2004 Indian Ocean earthquake and tsunami caused significant reef damage at some sites, but many are recovering.

### *Asia and Australia*

- **South-east Asia:** The Coral Triangle Initiative in Indonesia, Philippines, Eastern Malaysia, Papua New Guinea, Timor Leste and the Solomons has been initiated in an attempt to reverse the massive degradation of these reefs at the global centre of reef biodiversity. We include the first data for Timor Leste. Over-fishing, increasing sedimentation and urban and industrial pollution from rapid economic development are accelerating reef degradation faster than governments and NGOs can implement conservation. More than 50% of the region's mangroves have been lost.
- **North-east Asia:** Coral reefs have shown an overall decline since 2004 with most reefs coming under significant levels of human pressures, as well as bleaching and COTS

stress. There are a few reefs with high coral cover, such as Dongsha Atoll between Taiwan and China. Increased coral reef monitoring and research, including the establishment of a regional database, is occurring in Japan, Hong Kong, Taiwan and Hainan Island in China, and the region is stimulating more awareness and cooperation by having held the Asia Pacific Coral Reef Symposium in Hong Kong in 2006 and planning another for Thailand in 2010.

- **Australia and PNG:** Reefs of Australia continue to be well managed and relatively stable with no major climate change or cyclone events damaging the reefs since 2004. Management continues to set the benchmark for best practice, both in Eastern Australia on the Great Barrier Reef and, more recently, off Western Australia. Particular features are the effective partnerships between coral reef science and management. The situation is the reverse in Papua New Guinea with inadequate coral reef conservation and monitoring, with most of this being performed via large NGOs working with local communities. PNG still has vast areas of healthy and biodiversity-rich coral reefs but human pressures, both from within and externally, are increasing.

## ***Pacific Ocean***

- **Micronesia:** There has been good recovery of reefs in Palau and increasing efforts at reef monitoring and conservation in all countries. The Micronesia Challenge (p. 48) has raised considerable awareness of problems facing coral reefs and stimulated considerable capacity building, monitoring and conservation through the establishment of more MPAs including the massive PIPA World Heritage site. These reefs have remarkable recovery potential, thus the outlook remains encouraging;
- **South-west Pacific:** Climate-related coral bleaching continues to be the greatest threat to reefs of the South-west Pacific as human impacts, although growing, are not resulting in major reef loss over large scales. The University of the South Pacific and the CRISP program (see p. 45) are building more capacity for monitoring and conservation, with the Locally Managed Marine Area network developed in Fiji leading the way in the establishment of community managed MPAs: periodically harvested reserves have significantly higher target fish biomass than fished areas. Large reef areas of New Caledonia have gained World Heritage recognition;
- **Polynesia Mana – South-east Pacific:** This is also the situation in the South-east Pacific (Polynesia) with no major changes since 2004 and a gradual increase in reef awareness and conservation activities. There are many coral reefs surrounding uninhabited islands with climate change bleaching and ocean acidification as the only threats. These are considered as ideal targets for the creation of ‘reservoir’ protected areas to protect species threatened with over-exploitation or other human stresses;
- **US Pacific:** The USA recognised the global importance of the North-west Hawaiian Islands and have declared the Papahānaumokuākea Marine National Monument MPA. Management is increasing around the Main Hawaiian Islands, but over-fishing and sediment pollution continue as major threats. The depletion of aquarium species is being addressed through the establishment of industry recognised MPAs;

**The wider Caribbean:** These reefs suffered massive losses during the major climate related events of 2005 with all regions of the Wider Caribbean affected by record coral bleaching and hurricane damage.

- **US Caribbean:** Reefs of the US Caribbean are the focus of increased scientific and conservation efforts and results are variable with some improvements but also major

| Region              | Monitoring Level (%) |              |             | Coverage         | Confidence Level |
|---------------------|----------------------|--------------|-------------|------------------|------------------|
|                     | High Level           | Medium Level | Lower Level |                  |                  |
| Cold water reefs    |                      |              |             | Minimal          | Fair             |
| Red Sea             | 10                   | 30           | 60          | Low to Moderate  | Fair             |
| The Gulfs           | 10                   | 30           | 60          | Low to Moderate  | Fair             |
| Eastern Africa      | 25                   | 35           | 40          | Moderate to High | Moderate         |
| SW Indian Ocean     | 30                   | 40           | 30          | Moderate to High | Moderate         |
| South Asia          | 30                   | 20           | 50          | Moderate to High | Moderate         |
| SE Asia             | 40                   | 40           | 20          | Low to High      | Moderate         |
| E & N Asia          | 35                   | 30           | 35          | Moderate to High | Moderate         |
| Australia,          | 60                   | 25           | 15          | Extensive & High | High             |
| Papua New Guinea    | 5                    | 10           | 85          | Low              | Fair             |
| SW Pacific Islands  | 25                   | 35           | 40          | Moderate to High | Moderate         |
| Polynesian Islands  | 25                   | 25           | 50          | Low to High      | Fair             |
| Micronesian Islands | 35                   | 30           | 35          | Moderate to High | Fair             |
| Hawaiian Islands    | 65                   | 35           | 10          | Extensive & High | High             |
| US Caribbean        | 85                   | 10           | 5           | Extensive & High | High             |
| North Caribbean     | 35                   | 25           | 40          | Low to High      | Moderate         |
| Central America     | 40                   | 35           | 25          | Low to High      | Moderate         |
| Lesser Antilles     | 20                   | 30           | 50          | Low to Moderate  | Fair             |
| S Tropical America  | 30                   | 40           | 30          | Moderate         | Moderate         |

*This table summarises the extent of data collection and an assessment of the reliability of methods used to generate the data in coral reef countries and states around the world. Three levels of monitoring are recognised: High Level at species/genus level for corals and fish with high level reliability and repeatability, usually performed by trained scientists; Medium Level at 'lifeform' or similar category with moderate to high reliability and possibly with irregular repetitions, and performed by scientists or well trained volunteers and dive operators ; and Lower Level, either performed with timed swims or manta tow, or employing semi-trained volunteers, this category also indicates that large areas have not been observed. The Coverage details the extent of monitoring within the country that feeds into the Confidence category, which is a subjective assessment of the confidence that can be placed on these assessments.*

coral reef losses. The reefs immediately adjacent to Florida are showing minimal recovery as pollution and excessive tourism threats impede management efforts. More remote reefs, like the Tortugas and Flower Garden Banks are quite healthy, but Puerto Rico and the US Virgin Islands are threatened by over-fishing and pollution from the land, all compounded by coral bleaching and disease. The US Congress is currently revising the 'Coral Reef Conservation Act' to include reef restoration, strengthened international reef conservation programs and partnerships;

- **Northern Caribbean and Western Atlantic:** Reefs in the Northern Caribbean were also severely damaged in 2005 despite some increases in conservation efforts. There is a wide disparity in the economic status of these countries with some wealthier states applying considerable conservation efforts, such as Bermuda and the Cayman Islands, whereas others have minimal capacity and political will for conservation, e.g. Haiti. There are some encouraging signs of coral recovery after major losses in the 1980s and 1990s, especially around Jamaica, but unusually frequent and intense hurricanes are affecting reef recovery;
- **Lesser Antilles:** The 2005 coral bleaching caused major damage in the Lesser Antilles where coral cover was reduced by about 50% on many reefs. Recovery has been slow, or non-existent, in reefs under high human pressures. Algal cover has increased and coral diseases have been particularly prevalent since 2005. Most of these small islands depend heavily on their coral reefs for tourism income and fisheries and this awareness is increasing calls for reef conservation. This will be advanced considerably by those countries joining the Caribbean Challenge;
- **Mesoamerican Barrier Reef and Central America:** There has been a similar decline in reef status along the Mesoamerican Barrier reef, after a long series of losses that started in the 1980s. Bleaching and especially hurricanes in 2005 caused considerable destruction around Cozumel. The trend is for decreasing coral cover (averaging around 11% since 2004), and some reefs have lost more than 50% coral cover. Major programs have considerably raised capacity and improved management of MPAs but sedimentation and over-fishing continue to impede reef recovery;
- **Southern Tropical Americas:** Finally there is a mix of good and bad news about reefs in the Southern Tropical Americas. Areas close to land continue to suffer from pollution and sediment runoff, however, many more remote reefs are showing increases in coral cover. There have been some increases in monitoring management activities, especially in efforts to conserve the reefs of Brazil.

## RÉSUMÉ DE L'ÉTAT DES RÉCIFS CORALLIENS MONDIAUX: 2008

Traduction FLORENCE DAMIENS et BERNARD SALVAT

L'état de santé des récifs coralliens mondiaux a profondément évolué depuis le dernier rapport de 2004. Certains récifs ont bien récupéré après des dégradations d'origine anthropique et suite au phénomène de blanchissement de 1998, provoqué par le réchauffement climatique. Cependant, le tsunami de décembre 2004, d'autres phénomènes de blanchissement, plus nombreux cette fois-ci, ainsi que les pressions humaines ont ralenti, voire empêché, la récupération d'autres récifs.

Les estimations présentées dans cet ouvrage rassemblent les opinions de 372 chercheurs et gestionnaires de 96 nationalités, spécialisés dans l'étude et la gestion des récifs coralliens. Selon ces experts, le monde a presque perdu 19% de ses récifs coralliens ; 15% des récifs restants risquent sérieusement de disparaître dans les 10 à 20 prochaines années et 20% de plus sont menacés de disparition dans 20 à 40 ans. Ces estimations ont été réalisées sans prendre en compte les menaces liées au réchauffement climatique, ni les moyens qui pourraient être mis en place afin de préserver efficacement les récifs et leurs ressources. 46% des récifs mondiaux sont cependant considérés comme étant en bon état et exempts de menaces de destruction immédiate, à l'exception de celles liées au réchauffement climatique, actuellement difficiles à prévoir.

En cette année 2008, déclarée Année Internationale des Récifs Coralliens, un mélange de bonnes et de mauvaises nouvelles est présenté dans cet ouvrage, intitulé « Status of Coral Reefs Of The World: 2008 ». En effet, plusieurs événements majeurs ont endommagé les récifs coralliens depuis décembre 2004, date de publication des Status Of Coral Reefs Of the World: 2004. Cependant, des avancées majeures ont été réalisées afin de protéger les récifs coralliens mondiaux. En résumé, les récifs ont été le théâtre de certaines avancées comme de certains reculs :

- Si le tremblement de terre et le tsunami du 26 Décembre 2004 ont coûté la vie à de nombreuses personnes et affecté grandement les pays de l'Océan Indien, ils ont été également synonymes de dégradation des récifs coralliens de la région. Cependant, l'échelle de ces dégradations n'est pas comparable à celle des pertes humaines. (Box p.130)
- L'année 2005 a été l'année la plus chaude dans l'hémisphère Nord depuis 1998, provoquant des phénomènes massifs de blanchissement ainsi que la formation de cyclones au sein du bassin Caraïbe, tuant de nombreux coraux et dégradant d'autant plus leurs récifs.
- La dégradation des récifs coralliens proches des zones à forte densité de population se poursuit, provoquant une diminution de la couverture corallienne, des peuplements de poissons et probablement de la biodiversité. De telles dégradations ont également lieu au sein du « Triangle du Corail », épiceutre mondial pour la biodiversité marine (p. 55).
- Un nombre croissant d'études tend à prouver que le réchauffement climatique mondial a des répercussions directes sur de plus en plus de récifs coralliens. En outre, il apparaît clairement que l'acidification progressive des océans provoquera des dommages de plus en plus graves dans le futur.
- Les études socio-économiques concernant les récifs coralliens sont de plus en plus nombreuses et s'avèrent être davantage prises en compte dans la gestion des récifs coralliens afin de renforcer et de revivifier les méthodes traditionnelles de gestion, en particulier dans le Pacifique, où nombre d'entre elles sont demeurées intactes.

- Le déclin actuel des récifs coralliens aura des graves conséquences pour environ 500 millions de personnes, dépendant directement des récifs et de leurs ressources pour se nourrir, protéger leurs côtes, obtenir des matériaux de construction et bénéficier des retours financiers de leurs activités touristiques. Ce chiffre inclut les 30 millions de personnes dont l'habitat et le mode de vie dépendent exclusivement des récifs coralliens.
- Les gestionnaires des récifs coralliens vont devoir faire face à des problèmes de plus en plus nombreux: la population vivant sur les côtes ne cesse d'augmenter et devrait atteindre 50% de la population mondiale d'ici à 2015, exerçant dès lors une pression non soutenable sur les ressources côtières. De plus, l'augmentation du prix des produits alimentaires de base et du prix du pétrole, ainsi que l'actuelle crise financière mondiale se traduisent, dans de nombreux pays pauvres, par une surpêche chronique et un épuisement des stocks de poissons. Enfin, à terme, les récifs gérés seront moins attractifs, car constitués d'espèces coralliennes moins nombreuses (mais plus résistantes). Une telle évolution obligerait également à reconsidérer les activités touristiques liées aux récifs coralliens.
- Etablir davantage d'Aires Marines Protégées, reliées entre elles afin de former de véritables réseaux et gérées par tous les acteurs concernés, en particulier par les communautés riveraines, demeure la meilleure solution.

Face à ces résultats inquiétants, certaines avancées ont vu le jour :

- Deux immenses Aires Marines Protégées (AMP) consacrées aux récifs coralliens ont été établies dans le Pacifique: le Monument National Marin de Papahānaumokuākea, couvrant les îles du nord-ouest d'Hawaï et l'Aire Marine Protégée des Îles Phoenix, déclarés respectivement par les gouvernements des États-Unis et de Kiribati (Boîtes p. 224, 195) ;
- Les récifs coralliens à la Nouvelle-Calédonie ont été classés au Patrimoine Mondial de l'Humanité (Box p.184). D'autres récifs ont été portés candidats.
- Dans l'Océan Indien, et en particulier aux Seychelles, aux Chagos et aux Maldives, comme à Palau dans le Pacifique Ouest, l'état des récifs coralliens a continué à s'améliorer depuis le phénomène dévastateur de blanchissement de 1998.
- En Décembre 2007, le président indonésien, M. Yudhoyono, a rassemblé des soutiens et des fonds provenant des dirigeants du monde entier en faveur du projet « Initiative pour le Triangle de Corail » afin de conserver les ressources des récifs coralliens du Sud-Est asiatique. (p. 55)
- Cette initiative a été étendue aux pays du Pacifique Ouest, qui bordent le Triangle du Corail, lorsque le président de Palau, M. Remengesau, a lancé, avec d'autres dirigeants politiques, le « Challenge de Micronésie », s'engageant ainsi à consacrer 20% de la terre et 30% des eaux qui sont sous leur contrôle à des aires protégées organisées en réseau. (p. 48)
- Peu après, le premier ministre des Bahamas, M. Ingraham, a rassemblé quatre de ses confrères des pays voisins pour former le « Challenge des Caraïbes », visant à conserver 30% de leurs ressources côtières. (Box p.280)

D'autres actions encourageantes en faveur des récifs coralliens ont également été menées, dont :

- L'Initiative Internationale Pour les Récifs Coralliens, actuellement codirigée par le Mexique et les États-Unis, a déclaré l'année 2008 « Année Internationale des Récifs Coralliens », et a développé des campagnes majeures de sensibilisation à travers le monde.

- En juillet 2008, le 11<sup>ème</sup> Symposium International sur les Récifs Coralliens a rassemblé, à Fort Lauderdale aux Etats-Unis, 3 500 scientifiques, gestionnaires et décideurs politiques avec pour objectif un développement des recherches scientifiques au service de la gestion et de la conservation des récifs. (p. 43)
- Reef Check a rassemblé 20 700 signatures en faveur de la pétition intitulée "Déclaration des Droits des Récifs Coralliens", lancée lors de cette Année Internationale des Récifs Coralliens.
- Le groupe environnemental Pew travaille actuellement avec les gouvernements de pays en développement (PED) pour mettre en place de très vastes aires de protection absolue (no-take areas). Sont ainsi particulièrement concernés : la Mer de Corail australienne, les Iles Mariannes du Nord, l'Archipel des Chagos dans l'Océan Indien, la fosse des Kermadec située au nord-est de la Nouvelle-Zélande. Le « Coral Reef Targeted Research and Capacity Building for Management Program » a établi quatre Centres d'Excellence afin de développer les compétences locales pour la gestion des récifs coralliens. (p. 47)
- L'Initiative Corail pour le Pacifique (CRISP) a développé ses actions dans 17 pays insulaires du Pacifique. Des progrès considérables sont à noter quant au développement de compétences et d'expertises locales. (p.45)
- Les gouvernements français et américain ont chacun publié en 2008 un rapport majeur sur l'état de leurs récifs. Le réseau GCRMN du Pacifique Sud-Ouest a également produit un rapport en 2007. Les rapports français et du nœud Pacifique Sud-Ouest ont été publiés selon le format du GCRMN.
- The Global Environment Facility a accordé 100 millions de dollars au fonds « Pacific Alliance for Sustainability » afin de rassembler les pays du Pacifique pour la conservation de leur environnement. Une partie de ce fonds sera allouée à l'Initiative pour le Triangle de Corail et au Challenge de Micronésie.
- L'Allemagne a lancé un nouveau centre de recherche consacré à la biodiversité et au climat, au sein de l'Institut de recherche de Senckenberg à Francfort. L'étude des récifs coralliens sera l'un des thèmes majeurs de ce nouveau centre.

## RECOMMANDATIONS POUR LA CONSERVATION DES RÉCIFS CORALLIENS

Ces recommandations sont un résumé basé sur les 17 chapitres régionaux du livre ainsi que sur les rapports d'autres spécialistes. Des recommandations plus spécifiques à chaque région sont détaillées à la fin de la plupart des chapitres. Sont présentées ici les actions que les auteurs et contributeurs considèrent comme urgentes et plus que nécessaires afin de conserver les récifs coralliens pour les générations futures:

- **Combattre d'urgence le réchauffement climatique:** la vitesse actuelle d'évolution du réchauffement climatique place ce dernier au premier rang des menaces portées aux récifs coralliens et aux communautés humaines côtières sur le long terme. Nous demandons à la communauté internationale de collaborer, au travers de ses gouvernements, agences, ONG, institutions académiques et en particulier de ses entreprises, afin de réduire d'urgence le taux actuel d'émissions de gaz à effet de serre. Une telle réduction ne peut se faire qu'à travers une diminution de la consommation énergétique, le développement de mécanismes d'incitation -à l'instar des marchés de droits à polluer-, de technologies permettant la production d'une énergie durable et de réduire la quantité de ces gaz injectés dans l'atmosphère (CO<sub>2</sub> en particulier). Ces mesures sont indispensables pour assurer la pérennité des récifs coralliens jusqu'au siècle prochain.

- **Maximiser la capacité de résilience des récifs coralliens** (en minimisant les pressions humaines directes sur les récifs) : la menace essentielle depuis des décennies pour les récifs résulte des activités d'origine anthropique affectant directement les récifs: surpêche et pêche destructrice, pollution par sédimentation due à un mauvais usage des terres, pollution par nutriments ou autres, destruction des habitats due à un développement non durable. Contrôler ces menaces, qui portent atteinte aux récifs dans le monde -tout particulièrement dans les pays en développement, petits territoires insulaires compris-, permettrait de les protéger et d'augmenter leur récupération à la suite d'effets négatifs dus au réchauffement climatique. Ces pays ont besoin d'aide afin d'améliorer l'aménagement de leurs bassins versants et leur gestion côtière. Pour cela, de meilleures connaissances et compétences dans ce domaine leur sont indispensables, ainsi que des fonds, clefs d'une gestion basée sur les communautés locales, développant des modes de vie alternatifs et réduisant par là même les pressions appliquées aux récifs.
- **Étendre la gestion d'aires protégées:** Améliorer la gestion des Aires Marines Protégées (AMP) existantes est indispensable si l'on veut restaurer les stocks de poissons qui s'épuisent et protéger les biens et services que représentent les récifs, sources de soutien aux économies et modes de vie côtiers. Pour ce faire, il est nécessaire de contrôler les bassins versants adjacents afin de prévenir toute pollution par apports de nutriments ou de sédiments et de créer des zones-tampon améliorant la protection des récifs.
- **Inclure davantage de récifs au sein des AMP:** Inclure davantage de récifs au sein d'AMP gérées efficacement est un outil de gouvernance qui s'est avéré être une mesure positive pour garantir leur conservation et leur exploitation durable. Ces AMP devraient contenir une proportion significative de zones de cantonnement de pêche et zones de protection absolue, reliées entre elles en réseau et soumises à un plan de gestion à plus large échelle. Les PED ont besoin d'assistance pour mettre en place leurs réseaux d'AMP et les bases d'une gouvernance préalable à toute gestion côtière intégrée.
- **Protéger les récifs isolés:** de nombreux récifs coralliens se situent loin de toute terre et de toute population humaine. Protégés, ces récifs pourraient jouer le rôle de réservoir de biodiversité afin d'aider à reconstituer les récifs épuisés. Nous recommandons d'établir davantage d'AMP afin d'y inclure une large proportion de ces récifs isolés, à l'instar de ceux situés à l'ouest d'Hawaï, ceux de Kiribati ou encore de la Mer de Corail au large de la Grande Barrière de Corail. Les pays développés sont probablement ceux qui possèdent les meilleurs moyens de gouvernance et de mise en application pour établir de plus vastes aires marines protégées isolées.
- **Améliorer l'application concrète des législations concernant les AMP:** le manque d'application concrète des systèmes de gouvernance reste un problème majeur à résoudre: différents zones et niveaux d'exploitation des ressources doivent être mis en place et respectés grâce à une surveillance effective. De nombreux pays ont besoin d'aide pour établir des systèmes de surveillance effectifs en fonction des différents environnements marins ou côtiers, et ce, tout en veillant à respecter les pratiques et valeurs locales.
- **Améliorer la prise de décision politique grâce à un meilleur suivi environnemental et socio-économique:** face aux menaces croissantes liées au réchauffement climatique, il est urgent d'investir davantage dans l'étude et le suivi des récifs afin de s'assurer que des données plus complètes soient transmises aux gestionnaires de ressources naturelles et décideurs politiques. Ainsi aux seraient prises des actions appropriées pour protéger, au sein d'AMP, les récifs qui s'avèreraient être les plus résistants face au changement climatique.

### SEALS ON CORAL REEFS: EXTINCT IN THE CARIBBEAN, THREATENED IN THE PACIFIC

Several hundred years ago, the coral reefs of the Caribbean had 6 times more fish than today and this change is linked to the extinction of the Caribbean monk seal, *Monachus tropicalis*, in 1952. Scientists examined 17<sup>th</sup> and 18<sup>th</sup> century records of 13 colonies across the Caribbean with large seal numbers. The seals downfall was because sailing ships targeted these colonies to replenish meat supplies, harvest the fur and collect seal oil to lubricate sugar plantation machinery. By the end of the 19<sup>th</sup> century, the low numbers made harvesting uneconomical; however natural history museums and private collectors plundered the last populations on the remote atolls for their skeletons. For example, a natural history expedition in 1911 to Mexico killed 200 seals, and virtually destroyed one of the few remaining colonies. Scientists have calculated that there were 233 000 to 338 000 monk seals throughout the Caribbean, with adult seals eating 245 kg and juveniles eating 50 kg fish per year. They calculated that fish populations on most Caribbean reefs to support these seals would be 4 to 6 times larger than current populations – similar to fish populations on remote Pacific reefs.

The demise of the seals and severe over-fishing occurred in parallel, providing more evidence that a major threat to Caribbean coral reefs is past and present over-fishing. Any other flow-on effects to reef ecosystems resulting from the extinction of monk seals are unknown. Disruption of food chains, particularly the removal of major predators, often results in major impacts with the possibility that some species could take advantage of the lack of predation and dominate the reefs; a topic of considerable conjecture (from McClenachan & Cooper, 2007. Proceedings Royal Society of London B, Doi:10.1098/rspb.2007.1757, published online).

Seal populations are also under threat at their last remaining refuges in the Pacific. Populations of the Hawaiian monk seal, *Monachus schauinslandi*, have dropped by 60% since they were first estimated in the 1950s (reported in 2004 global status report). Hopefully, the declaration of the Papahānaumokuākea Marine National Monument will provide sufficient protection to prevent these monk seals following their Caribbean cousins into extinction.

The situation with the two eared 'seals' on the Galapagos Islands is quite different. Fur seals (*Arctocephalus galapagoensis*) were nearly hunted to extinction in the 1800s for their rich fur, even though the peak population was probably only 50,000: in 1905 a California Academy of Sciences expedition did not find a single fur seal. Fortunately, hunting stopped and populations have bounced back from the brink of extinction, especially because these fur seals mainly eat offshore squid and do not compete directly with the inshore fishing industry. They, however, do suffer population crashes during very strong El Niño events. The Galapagos sea lion (*Zalophus wollebaeki*) was not targeted by early sealers, however, they compete with fishermen for inshore food resources and populations may be declining due to this competition, increases in disease, and some sea lions are killed illegally to extract the penis to sell in Asia as an aphrodisiac (from Scott Henderson, s.henderson@conservation.org)

## RESUMEN EJECUTIVO

# ESTADO DE LOS ARRECIFES CORALINOS DEL MUNDO: 2008

Translation PEDRO ALCOLADO AND ALESSANDRA VANZELLA-KHOURI

Los arrecifes coralinos del mundo han efectivamente marcado el tiempo desde el último informe en 2004. Algunas áreas se han recuperado bien después del blanqueamiento a causa del cambio climático en 1998, mientras que en el Océano Índico más eventos de blanqueamiento y presiones humanas han demorado o revertido la recuperación.

Los estimados obtenidos a través de las opiniones de 372 científicos y administradores de arrecifes coralinos de 96 países, indican que el mundo, efectivamente, perdió 19% de los corales existentes; que 15% están seriamente amenazados de perderse en los próximos 10 a 20 años y que 20% están en peligro de desaparecer en 20 a 40 años. Estos últimos dos estimados se hicieron bajo el escenario de “condiciones normales”, sin considerar las sombrías amenazas del cambio climático mundial o que un manejo efectivo en el futuro podría conservar más arrecifes coralinos. Sin embargo, hay un 46% de los arrecifes coralinos del mundo que se consideran saludables, y bajo ninguna amenaza inmediata de destrucción, excepto por la amenaza “actualmente impredecible” del clima mundial. Estas predicciones implican muchas salvedades como se explica abajo.

En 2008, Año Internacional de los Arrecifes, hay una mezcla de noticias negativas y positivas en este reporte Estado de los Arrecifes Coralinos del Mundo: 2008. Varios eventos de importancia han dañado los arrecifes coralinos desde diciembre de 2004, cuando se publicó el reporte anterior “Estado de 2004”. Sin embargo, se han dado pasos muy positivos para conservar los arrecifes coralinos del mundo; en esencia, unos pasos adelante y otros atrás, tales como:

- El enorme terremoto y tsunami del Océano Índico el 26 de diciembre de 2004 golpeó con una enorme pérdida de vidas y destrucción a los países de la región. Hubo daño considerable a los arrecifes de coral, pero no comparable a la magnitud de las pérdidas humanas (Recuadro p. 130);
- 2005 fue el año más caliente en el Hemisferio Norte desde 1998, que resultó en un blanqueamiento masivo de los corales, así como en huracanes a lo ancho del Gran Caribe que mató muchos corales, dañando aún más sus arrecifes;
- Los arrecifes coralinos cerca de grandes centros de población, continúan perdiendo cubrimiento de corales, poblaciones de peces y, probablemente, de biodiversidad. De hecho, esto está sucediendo alrededor del “Triángulo de Coral” el centro mundial de biodiversidad marina (p. 55);
- Existe evidencia creciente de que el cambio climático está causando un impacto directo en más y más arrecifes coralinos, con claras señales de que la acidificación creciente del océano causará daños mayores en el futuro;
- Las evaluaciones socioeconómicas en arrecifes coralinos están incrementando y se utilizan más en la toma de decisiones para el manejo. Estas evaluaciones se están empleando para fortalecer y revigorizar las estructuras tradicionales de manejo, especialmente en el Pacífico donde los regímenes tradicionales de manejo permanecen intactos;

- Sin embargo, el deterioro de los arrecifes coralinos tendrá consecuencias alarmantes para aproximadamente 500 millones de personas que dependen de ellos para la alimentación, protección costera, materiales de construcción, e ingresos del turismo. Esto incluye 30 millones que dependen casi totalmente de los arrecifes coralinos para su sustento o como terreno sobre el que viven;
- Los problemas para los que manejan los arrecifes coralinos están aumentando ya que 50% de la población mundial vivirá a lo largo de las costas hacia el 2015, lo que impondrá presiones insostenibles sobre los recursos costeros. Los arrecifes que queden y que ellos manejen contendrán corales menos atractivos pero más resistentes. Los incrementos en los precios de los alimentos y de los combustibles, así como la crisis financiera mundial, están resultando en sobrepesca y el agotamiento en serie de las poblaciones de peces en muchos países pobres; y
- La solución sigue siendo el establecimiento de Áreas Marinas Protegidas más efectivas, vinculadas en redes y manejadas por todos los actores interesados, especialmente las comunidades que viven de los arrecifes.

Oponiéndose a tales sombrías noticias, hay algunos avances importantes:

- Se han declarado dos enormes Áreas Marinas Protegidas (MPAs) para los arrecifes coralinos del Pacífico: el Monumento Nacional Marino Papahānaumokuākea, que abarca las Islas Hawaianas del nordeste, y el Área Protegida de las Islas Phoenix (PIPA), declaradas por los gobiernos de los Estados Unidos de América y Kiribati, respectivamente (Recuadros p. 224, 195);
- Grandes áreas de arrecifes coralinos alrededor de Nueva Caledonia han sido añadidas a la lista de Patrimonio Mundial (Recuadro p. 184) y están bajo consideración más áreas de otros lugares;
- Los arrecifes coralinos en el Océano Índico, especialmente en Seychelles, Chagos y las Maldivas, así como Palau en el Pacífico Oeste, han continuado recuperándose después del blanqueamiento devastador de 1998;
- En diciembre de 2007, el Presidente Yudhoyono de Indonesia ganó el apoyo y el financiamiento de líderes mundiales para la “Iniciativa del Triángulo de Coral” para conservar los arrecifes coralinos del Sudeste Asiático (p. 55);
- Esta iniciativa fue expandida para incluir los países del Pacífico Oeste que bordean el Triángulo de Coral, cuando el Presidente Remengesau de Palau, instigó el “Reto de Micronesia” comprometiéndose junto con otros líderes a conservar un 20% terrestre y 30% de las aguas como áreas protegidas vinculadas en redes (p. 48);
- Poco después, el Primer Ministro Ingraham de las Bahamas reunió a cuatro de sus vecinos para formar el “Reto Caribeño” cuyo fin es conservar 30% de sus recursos costeros (Recuadro p. 280).

Adicionalmente, ha habido otras actividades positivas para los arrecifes coralinos que incluyen:

- La Iniciativa Internacional de Arrecifes Coralinos, actualmente co-presidada por México y los Estados Unidos de América, declaró el 2008 como Año Internacional de los Arrecifes Coralinos y desarrolló importantes campañas de concienciación alrededor del mundo;
- El XI Simposio Internacional de Arrecifes Coralinos reunió 3,500 científicos, encargados de manejo y tomadores de decisiones en Fort Lauderdale, Florida USA en julio de 2008, para fortalecer la ciencia de la conservación de los arrecifes coralinos (p. 43)
- Reef Check organizó 20,700 firmas sobre la “Declaración de los Derechos del Arrecife”, petición que fue lanzada en el Año Internacional de los Arrecifes Coralinos;

- El Grupo Ambiental Pew está trabajando con los gobiernos de los países en desarrollo para declarar extensas áreas como reservas marinas de no-extracción incluyendo el Coral Sea en Australia; el norte de las Islas Marianas; el Archipiélago de Chagos, en el Océano Índico, y Kermadec Trench, al nordeste de Nueva Zelanda;
- El Programa de Investigación y Creación de Capacidades para el Manejo de Arrecifes Coralinos (Coral Reef Targeted Research and Capacity Building for Management Program) estableció cuatro Centros de Excelencia para crear capacidad científica para el manejo (p. 47)
- CRISP (Iniciativa para los Arrecifes Coralinos del Pacífico) ha expandido las operaciones a 17 islas del Pacífico con progreso considerable en la elevación de la capacidad para el manejo y la evaluación socioeconómica de los arrecifes (p. 45)
- Los gobiernos de Francia y los Estados Unidos de América elaboraron en el 2008 resúmenes importantes de informes nacionales; el Nodo del Pacífico Sudoccidental produjo en el 2007 un informe regional. Los informes de Francia y del Pacífico SO se presentaron en el formato del GCRMN;
- El Fondo para el Medio Ambiente Mundial (GEF) ha dedicado \$100 millones a la Alianza del Pacífico para la Sostenibilidad, para unir a los países de este Océano con el fin de conservar su ambiente. Parte de este dinero se está destinando a la Iniciativa del Triángulo de Coral y al Reto de Micronesia.
- Alemania ha lanzado un nuevo instituto para la biodiversidad y el clima en el Instituto Senckenberg en Frankfurt, que tendrá un importante componente sobre arrecifes coralinos.

## RECOMENDACIONES PARA LA ACCIÓN HACIA LA CONSERVACIÓN DE LOS ARRECIFES CORALINOS

Este resumen de recomendaciones se basa en los 17 capítulos regionales y los reportes de otros especialistas. Al final de la mayoría de los capítulos hay recomendaciones más detalladas y específicas. Lo que sigue es lo que muchos autores y quienes contribuyeron consideran urgentemente necesario para conservar los arrecifes coralinos para las generaciones futuras:

- **Combatir urgentemente el cambio climático mundial** – las tasas actuales del cambio climático imponen la mayor amenaza en un futuro a largo plazo para los arrecifes coralinos y las comunidades humanas costeras. Pedimos que la comunidad mundial, a través de sus gobiernos, agencias, ONGs, instituciones académicas y especialmente las entidades comerciales, que colaboren para reducir urgentemente la tasa actual de emisión de gases de invernadero por medio de reducciones en el uso de energía y el desarrollo de mecanismos de generación de energía o sistemas de comercio sostenibles, y desarrollar tecnologías para eliminar estos gases de la atmósfera, especialmente CO<sub>2</sub>, para asegurar que los arrecifes coralinos prosperen en el próximo siglo.
- **Maximizar la resiliencia de los arrecifes coralinos (minimizando las presiones humanas directas sobre estos)** – la segunda amenaza en importancia a los arrecifes proviene de las actividades humanas directas: sobrepesca y pesca destructiva; contaminación por sedimentos provenientes de mal uso del suelo; escurrimiento de nutrientes y otros tipos de contaminación; y pérdida de hábitats causada por un desarrollo insostenible. El control de estas amenazas, que están deteriorando los arrecifes en todo el mundo, especialmente en países en desarrollo incluyendo los pequeños estados insulares, mejorará su resiliencia para enfrentar el cambio climático. Estos países necesitan asistencia para mejorar el manejo de sus cuencas y costas fortaleciendo capacidades y otorgando fondos

para implementar manejo comunitario y desarrollar alternativas de vida que reduzcan la presión sobre los arrecifes.

- **Mejorar el manejo de las áreas protegidas** – es necesario mejorar el manejo de las áreas marinas protegidas existentes (AMP) para acelerar la recuperación de las poblaciones de peces agotadas y proteger los bienes y servicios de los arrecifes coralinos que sostienen las economías y medios de sustento costeros. Esto incluye el manejo de las cuencas adyacentes a fin de evitar la contaminación por nutrientes y sedimentos y así crear áreas de amortiguamiento que reforzarán las actividades de manejo de las AMPs.
- **Incluir más arrecifes en las AMPs** – un enfoque de gobernanza comprobado y efectivo para conservar arrecifes coralinos y promover su uso sostenible es incluirlos en AMPs manejadas con efectividad; preferiblemente que contengan una proporción significativa de reservas pesqueras, vinculadas a redes de AMPs y dentro de un marco más amplio de gobernanza. Los países en desarrollo necesitan asistencia para expandir sus redes de AMPs y establecer marcos de gobernanza para el manejo integrado costero.
- **Proteger arrecifes lejanos** – hay muchos arrecifes coralinos lejanos de las masas continentales y poblaciones humanas que, si se protegen, serán capaces de actuar como reservorios de biodiversidad para reabastecer arrecifes degradados. Recomendamos el establecimiento de más AMPs para incluir muchos de los arrecifes de islas remotas, como las del oeste de Hawai, las de Kiribati, y las de Coral Sea al este de la Gran Barrera de Arrecifes. Los países desarrollados pueden tener los mejores recursos de gobernanza y cumplimiento para declarar áreas protegidas remotas de mayor tamaño.
- **Mejorar el cumplimiento de las regulaciones en las AMPs** – Se requerirán sistemas de gobernanza capaces de implementar regulaciones para hacer frente al gran problema de regular el acceso a los ecosistemas manejados (incluyendo tipos y tasas de explotación de recursos). Muchos países necesitarán asistencia para establecer sistemas de cumplimiento efectivos, que funcionen en diferentes ambientes marinos y costeros y que no debiliten los valores y prácticas culturales locales.
- **Ayudar a mejorar la toma de decisiones mejorando el monitoreo ecológico y socioeconómico** – con las crecientes amenazas del cambio climático, existe una necesidad urgente de mejorar el monitoreo suministrando información a los gestores de recursos naturales y tomadores de decisiones para que se ejecuten acciones apropiadas para reducir las amenazas a los arrecifes y comunidades costeras.

# 1A. GLOBAL CLIMATE CHANGE AND CORAL REEFS: RISING TEMPERATURES, ACIDIFICATION AND THE NEED FOR RESILIENT REEFS

C. MARK EAKIN, JOAN KLEYPAS, AND OVE HOEGH-GULDBERG

## SUMMARY

- Coral reefs, both tropical and deep cold water, are global centres of biodiversity that are being damaged by a combination of direct human impacts and global climate change;
- The major climate change threats are increasing sea temperatures and increasing ocean acidity from rising atmospheric concentrations of carbon dioxide (CO<sub>2</sub>), as well as a predicted increase in storms;
- Higher than normal sea surface temperatures stress corals and cause coral bleaching, frequently with large scale mortality. Bleaching is the loss of algal symbionts and a reduction in the coral's energy producing systems; severe stress often results in coral mortality or reduces reproduction and their ability to stave off infectious disease;
- Increasing concentrations of CO<sub>2</sub> lower the pH of seawater (ocean acidification) with a coincident decrease in the concentration of carbonate ions. This reduces the capacity of corals and other calcifying organisms to make calcium carbonate skeletons. Ocean acidification also may increase the susceptibility of corals to bleaching during thermal stress.
- These threats, combined with local factors such as declining water quality and over-fishing, are reducing coral reef resilience to environmental change, changing reef structure coral abundance and community composition;
- The result will be a loss of biodiversity through the destruction of the habitats of other organisms;
- Action to conserve reefs is now urgent and must include: strong policies to reduce greenhouse gas emissions; effective management of local stresses; and research to improve conservation and restoration efforts. Only through such concerted action will corals survive the next two centuries as temperatures continue to rise.

## ENVIRONMENTAL CHANGES FROM CLIMATE CHANGE

Coral reefs are the world's most diverse marine ecosystems and are critical for the livelihoods of millions of people who depend on them. Despite this, the health of many coral reefs has declined for decades due to many local stresses; now climate change has the potential to devastate coral reefs around the world. Warming temperatures and ocean acidification are already affecting coral reefs, causing frequent bleaching events and slowing the formation of coral skeletons. We can avoid catastrophic damage to coral reefs but to do so means we must reduce both climate change and local threats. All available evidence suggests that time is running out and that soon conditions on the planet will be so severe that coral reefs will no longer thrive.

There is strong international consensus that the world is experiencing global climate change, that the rate of climate change is increasing, and that much of the change is due to human release of greenhouse gases. Before the industrial revolution, the atmosphere contained about 280 parts per million (ppm) of CO<sub>2</sub>; today it is 35% higher (>380 ppm) and the increase in CO<sub>2</sub> continues to accelerate faster than predicted.

Sadly, coral reefs are among the first major marine ecosystems in the world to be seriously damaged by global climate change. The most recent (4th) Intergovernmental Panel on Climate Change (IPCC) assessment states "Corals are vulnerable to thermal stress and have low adaptive capacity. Increases in sea surface temperature of about 1–3°C are projected to result in more frequent coral bleaching events and widespread mortality, unless there is thermal adaptation or acclimatization by corals." The IPCC listed the following changes as pertinent to coral reefs:

- Rising sea surface temperatures;
- Increasing concentrations of CO<sub>2</sub> in seawater;
- Sea level rise;
- Possible shifting of ocean currents;
- Associated rises in UV concentrations; and
- Increases in hurricanes and cyclonic storms.

Here we focus on the first two. We are highly confident that the increases in human-caused greenhouse gases in the atmosphere over the last century have caused most of the 0.7°C (1.3°F) rise in the average global temperature of the surface ocean, and the 0.5°C (0.9°F) rise in tropical coral reef water temperatures. The ocean absorbs between one-quarter and one-third of the CO<sub>2</sub> that is added to the atmosphere each year resulting in 'ocean acidification' from carbonic acid made by increasing concentrations of dissolved CO<sub>2</sub> in seawater. Average global ocean pH has already dropped from around 8.2 to 8.1.

There is strong international consensus that climate change and ocean acidification are already affecting shallow water corals and their symbiosis with dinoflagellate algae. There are vast areas of deep-sea corals that are also being affected; these largely unknown complex ecosystems provide major fish habitat, but are now considered at particular risk to ocean acidification (see p. 30). This chapter focuses on two major questions: 'How are temperature increases and ocean acidification acting together to threaten coral reefs?' and 'How can we help coral reefs survive during climate change?'

## RISING SEA SURFACE TEMPERATURES AND CORAL BLEACHING

Increasing sea surface temperatures (SSTs) in tropical/subtropical waters have moved reef-building corals 0.5°C closer to their upper thermal limits. Natural temperature variability can now push corals into temperatures that cause bleaching more readily than in the past. When SSTs exceed the summer maximum by more than 1°C for 4 weeks or more under clear tropical skies, corals bleach by expelling their symbiotic algae, revealing either the pale pastel colours of coral pigments or the brilliant white skeleton. If warmer conditions persist corals could die in large numbers. We now know that high temperatures speed up the normal photosynthetic process in the symbiotic zooxanthellae beyond their capacity to repair damage to photosynthetic systems. This produces toxic free oxygen radicals causing corals to eject the algae, losing their major source of energy. Even if corals survive, the stress increases the incidence of coral diseases and reduces corals' ability to reproduce. Disease was the final cause of much of the coral death after the 2005 Caribbean bleaching event.

Widespread and severe coral bleaching events already are becoming more common. Another 1°C rise is almost certain by the end of this century even if all greenhouse gas emissions stopped today: even this will make coral bleaching more frequent and severe. The potential of a 4°C rise could make bleaching an annual event: this will not provide sufficient time for coral reefs to recover between bleaching episodes. Under scenarios of a 2°C rise or more, coral dominated reefs are expected to largely disappear from many shallow coastal regions of the world.

**Why most genetic adaptation probably will not work:** A core assumption in the predictions of rapid reef decline is that genetic change in corals and their symbiotic algae will be insufficient to keep pace with climate change. Coral thermal stress thresholds have been relatively stable over 20 years with no measurable shift upwards. However, bleaching and mortality are increasing, indicating that stress thresholds are not changing rapidly enough to prevent bleaching.

An alternative hypothesis is that corals, via their symbiont zooxanthellae, may evolve rapidly by acquiring more thermally tolerant symbionts within a few decades. This would make corals more thermally tolerant and keep pace with rapid climate change. But this would require an adaptation at a rate of at least 0.2–0.4°C per decade and there is no evidence that corals can change their symbiotic relationships or develop temperature tolerance so quickly. No lasting changes have been observed in coral-zooxanthellae partnerships before and after major bleaching events. On-going research now seeks to enhance the coral acclimation/adaptation potential. While such an approach could enhance conservation, it remains untested. Another option for adaptation is 'Darwinian' selection to act on reef corals. Unfortunately, this natural selection process has culled many of the more sensitive coral species, leading to a loss of biodiversity and functional redundancy.

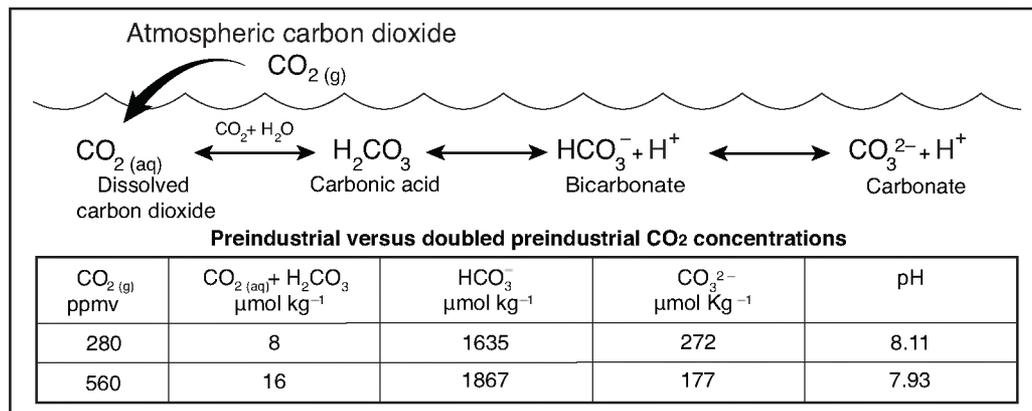
The 2007 IPCC Report predicts that climate changes will continue for hundreds of years, with increases in greenhouse gas emissions. Current predictions are that corals will not adapt to warmer water without stabilization or a decrease in greenhouse gas emissions. The best case scenario is that low emission technologies and removal of CO<sub>2</sub> from the atmosphere may stabilize global temperatures at 2°C above the present; however, coral populations will initially decrease with the loss of temperature sensitive species, hopefully to be replaced by more temperature resistant ones. Even this will cause the probable extinction of many corals and other species that depend on coral reefs for habitat and food. Current predictions are for concentrations

of CO<sub>2</sub> of 500–600 ppm, thereby increasing temperatures by 2–6°C and jeopardizing most of the important ecological services provided to the estimated 500 million people that depend partially or wholly on coral reefs for their daily food and resources.

### INCREASING CONCENTRATIONS OF CO<sub>2</sub> IN SEAWATER

Ocean uptake of CO<sub>2</sub> from the atmosphere reduces the severity of the greenhouse effect and climate change (and the temperatures that cause coral bleaching). Unfortunately, increased CO<sub>2</sub> alters the chemistry of seawater and lowers the pH (a lower pH means more acidic via a higher concentration of hydrogen ions). CO<sub>2</sub> levels in the surface ocean are expected to reach double pre-industrial levels within 40–50 years, and seawater pH will decrease by another 0.2 units. We have already seen a reduction in globally-averaged pH of the surface ocean of 0.1 pH units. This change in pH may seem small, but it is significant because:

- pH is measured on a logarithmic scale — a 0.1 decrease in pH is a 30% increase in ocean acidity;
- Surface ocean pH is already at its lowest in 800 000 years, and probably more than 20 million years;
- The speed of this change is likely to outstrip the ability of many organisms to adapt;
- Acidification interacts with other factors such as sea temperature rise and storm intensity to produce much larger impacts than each factor acting alone.



*This diagram illustrates what will happen to ocean chemistry as more CO<sub>2</sub> dissolves in seawater. When CO<sub>2</sub> concentrations in the atmosphere effectively double from pre-industrial levels, there will be an increase in dissolved bicarbonate and a decrease in the available carbonate in sea water. Thus it will become more difficult and energy consuming for coral reef animals and plants to make skeletons.*

**The significance of these changes:** Biological processes can be directly impacted by ocean acidification because of changes in pH, or by changes in the concentrations of dissolved carbon dioxide, bicarbonate ion or carbonate ion. Virtually every major biological function (photosynthesis, respiration rate, growth rate, calcification rate, nitrogen-fixation rate,

reproduction, and recruitment) can be affected by these chemical changes. Dissolved  $\text{CO}_2$  and bicarbonate are used in photosynthesis, thus seagrasses and some marine algae may benefit from  $\text{CO}_2$  increases. The decrease in the carbonate ion concentration, however, will reduce the ability of many organisms to form calcium carbonate ( $\text{CaCO}_3$ ) skeletons. The effects on shell and skeleton growth are the best studied of these responses. The calcification rates of almost all tropical and cold-water corals are likely to decrease by 20–50% by 2050. Under extreme conditions, some species lose their skeletons completely and are transformed into colonial anemone-like animals. Even if such ‘naked’ corals survive, they will not build reefs or provide the services of current coral reefs. Evidence now suggests that coral growth rates have already decreased by 15%, although it is unclear how much of this is due to ocean acidification versus temperature increases and other factors. Reduced calcification can either slow coral growth, making them less able to compete for space, or weaken coral skeletons increasing their vulnerability to erosion, storm damage and predation.

Crustose coralline algae (CCA) are also important reef calcifiers that appear to be particularly vulnerable to ocean acidification. CCA are abundant carbonate producers on many reefs, form the structural crust on reef flats, and attract settlement of new coral recruits. CCA secrete a form of calcium carbonate that is more easily dissolved than corals and experiments show that CCA growth rates and recruitment success will be greatly reduced under the ocean acidification conditions expected by 2100.

The responses in other groups, such as echinoderms and molluscs, will be mixed with some species responding poorly to ocean acidification, others showing little to no response, and some even increasing calcification, possibly at the expense of muscle mass. The varied responses reflect differences in the mineralogy and structure of the calcium carbonate, the biological process of calcification, and the evolutionary history of an organism. The net effects of ocean acidification on coral reefs are difficult to assess within these diverse communities, although a study of a natural  $\text{CO}_2$  seep in the Mediterranean showed a dramatic decrease in calcifying organisms near the seeps, while seagrasses and invasive algae thrived.

Coral reef ecosystems are unique because the excess production of calcium carbonate builds reef structure – the very basis of a coral reef habitat. As calcification declines and dissolution rises, the balance between reef growth and reef destruction will also change. Reefs with a low surplus of carbonate production, such as those at high latitudes or upwelling regions, may shift from net reef building to net reef loss within a few decades and will no longer keep up with rising sea levels. Coral reefs that grow in waters naturally high in  $\text{CO}_2$  (e.g. eastern Pacific) are less cemented, less developed, and suffer higher erosion rates than other reefs, suggesting that all coral reefs in the future will be structurally less robust as the oceans acidify. Even worse, recent laboratory work shows that the temperature threshold for bleaching is lowered as seawater  $\text{CO}_2$  increases. This means that rising atmospheric  $\text{CO}_2$  may cause coral bleaching in two ways — via ocean acidification as well as from tropical sea warming.

### **ACTIONS REQUIRED TO LIMIT CLIMATE CHANGE IMPACTS**

The loss of corals, and hence the framework of coral reefs that support thousands of other species, will result in considerable reduction of the goods and services provided by reefs, and reduce biodiversity through many local or total extinctions. For example, some corallivorous (coral eating) fish species may be lost, while herbivores may increase as algal food increases.

Many papers at the 2008 11<sup>th</sup> International Coral Reef Symposium (see p.43) focused on the combined harmful impacts of climate change, water quality, and fishing, with calls for simultaneous action to reduce all three threats. Coral reefs have flourished for millions of years. To help them survive the next few centuries, we must take three actions:

1. It is imperative that everyone reduce greenhouse gas emissions to prevent atmospheric CO<sub>2</sub> concentrations from exceeding 450–500 ppm. This target will be difficult to achieve without technological breakthroughs; nevertheless, temperatures will continue to rise and impact coral growth. Without concerted and immediate international actions we risk long lasting destruction of coral reefs.
2. Reefs will persist longer under the climate change stresses if their resilience is maintained. Resilience buys important time for recovery from the inevitable ecological shocks from climate change. Thus, declining water quality, harmful fishing, and habitat destruction, must be reduced through effective management. This is the job for local resource managers working in concert with the international community.
3. Increased investment in research on reef restoration and in methods to enhance the natural resilience in corals is necessary, including drastic measures such as cooling or shading high value reefs during bleaching events.

#### **AUTHOR CONTACTS**

The manuscript contents are solely the opinions of the authors and do not constitute a statement of policy, decision, or position on behalf of NOAA or the US Government. C. Mark Eakin, Coral Reef Watch, National Oceanic and Atmospheric Administration, mark.eakin@noaa.gov; Joan Kleypas, National Center for Atmospheric Research Boulder, Colorado, USA, kleypas@ucar.edu; Ove Hoegh-Guldberg, Centre for Marine Studies, University of Queensland, Australia. oveh@uq.edu.au.

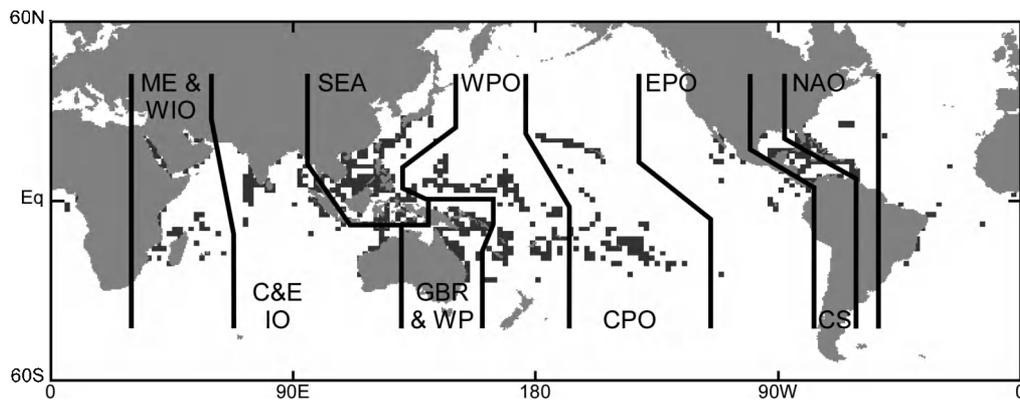
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# 1B. GLOBAL CLIMATE CHANGE AND CORAL REEFS: REEF TEMPERATURE PERSPECTIVES COVERING THE LAST CENTURY

SCOTT HERON, WILLIAM SKIRVING, MARK EAKIN

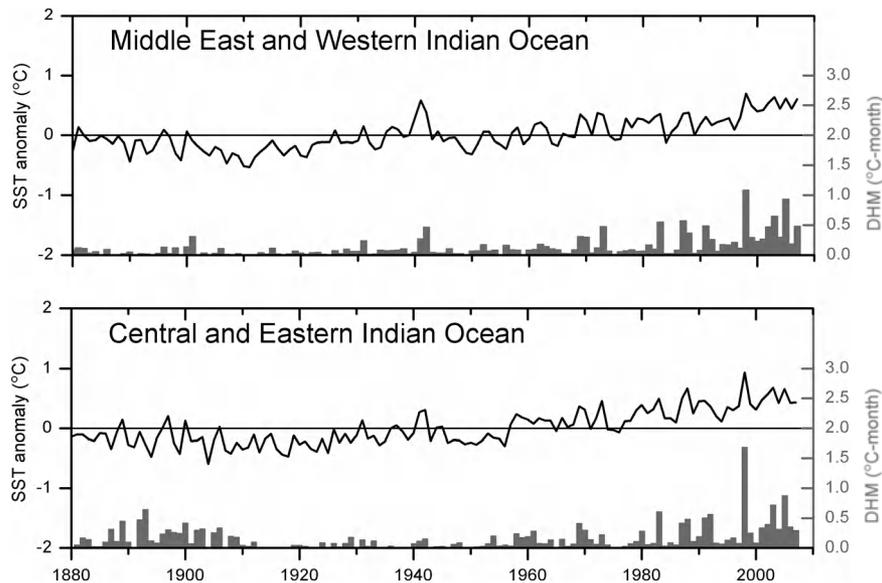
Temperatures and thermal stress at reef locations around the globe have generally increased over the past 128 years with regional trends in the range of 0.24–0.59°C per century. For most coral reef regions the levels of thermal stress are unprecedented within the last two decades. While satellite monitoring of the waters surrounding coral reefs has provided an accurate and timely measure of current and recent conditions, these have been put into a century-long context using long-term water temperature data collected by passing ships and buoy-mounted instruments. This gives an insight into how climate has been changing over the last century and affecting coral reef ecosystems around the world.



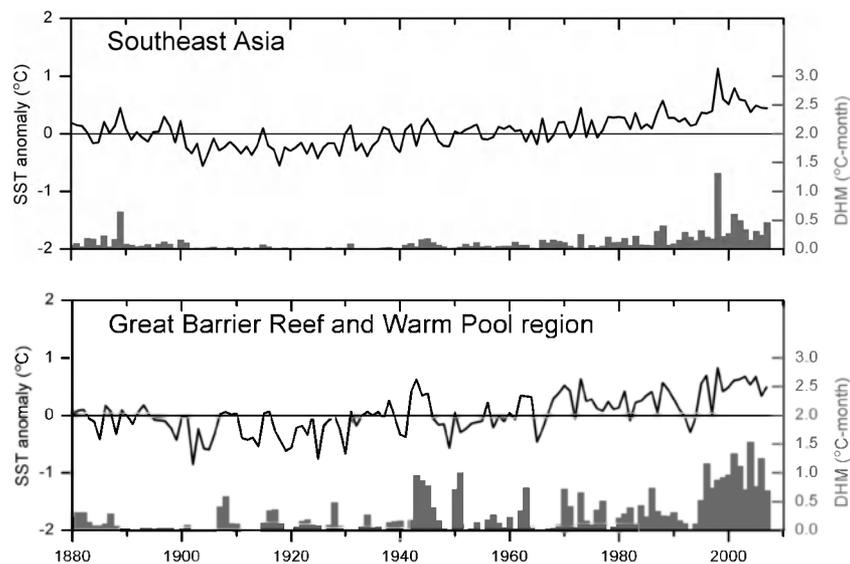
*This map shows global reef locations (squares) and 9 regional groups used to investigate long-term temperature patterns. Regional groups are (from left): Middle East and Western Indian Ocean; Central and Eastern Indian Ocean; Southeast Asia; Great Barrier Reef and Warm Pool; Western Pacific Ocean; Central Pacific Ocean; Eastern Pacific Ocean; Caribbean Sea; and North Atlantic Ocean.*

**Methods:** The Extended Reconstructed SST (ERSST) version 3 dataset was produced by mapping in situ observations (ship measurements and buoy data from 1854 to the present) and satellite SST (since 1985) onto a 2° × 2° grid at monthly resolution using statistical techniques. Measurements prior to 1880 were extremely sparse, with increasing errors; thus this analysis starts from 1880. The biggest issue with using this dataset is the spatial resolution mismatch

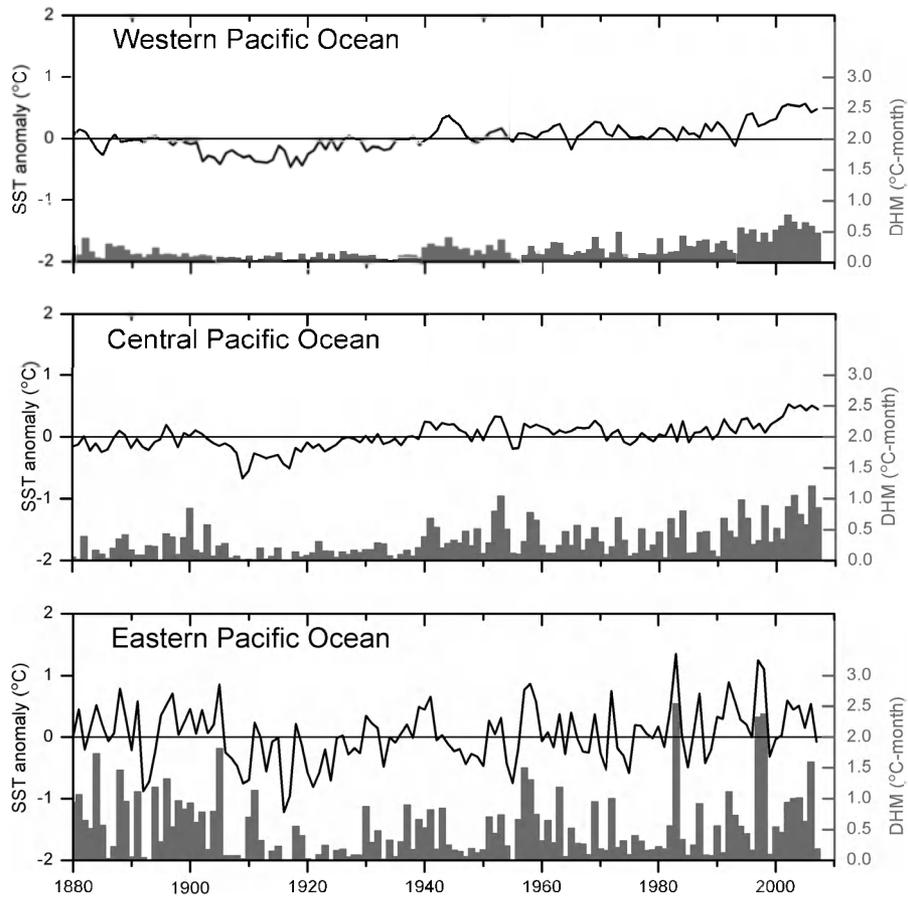
between the scale of conditions on individual coral reefs (kilometres) to the pixel-size of the ERSST analyses (~200 km). To make sure that the ERSST data are relevant to reef locations, they were compared with an established satellite temperature dataset. NOAA Coral Reef Watch (CRW) monitors thermal conditions at reef locations around the world using satellite data. These products are produced in near real-time at 0.5° (~50 × 50 km) resolution, twice each week, and are based on night-time SST values. The SST product is not an average of temperature across each 0.5° pixel but uses only the warmest 9 km region. This helps to avoid clouds and provides a stable measurement to monitor thermal stress around coral reefs. The 0.5° SSTs are used to make the Degree Heating Week (DHW) index, which combines the magnitude and duration of summertime thermal stress experienced by ocean ecosystems. CRW has also constructed a dataset for 1985–2006 that mimics the methods for the near real-time data, based on data from the NOAA/NASA AVHRR Oceans Pathfinder Program (PFSST). This dataset was used to validate the ERSST data. Comparisons were made between ERSST and PFSST data from reef-containing pixels for the period of overlap between the datasets, 1985–2006. The datasets were evaluated for each pixel-pairing to determine if there was a significant linear correlation between the broad-scale (ERSST) and reef-specific (PFSST) values. Of 711 ERSST reef pixels, 101 were excluded due to poor linear correlation with PFSST values ( $R^2 < 0.50$ ) or because they spanned two distinct water masses. Based on similar pixel-relationships with PFSST data, ERSST data were grouped into 9 regional groups. For each remaining reef pixel, monthly climatologies were created by averaging ERSST values for the period 1901–2000 and SST anomalies calculated. Monthly anomalies were averaged across regional groups and for each year to show the regional trends in temperatures. To examine the accumulated thermal stress, a DHM index was calculated, following previous long-term studies. For this study, positive anomalies of SST, as compared with the warmest month's temperature, were calculated and averaged across each regional group for each month. These values were then accumulated across a three-month window, mimicking the accumulation of DHW over 12 weeks. Rather than look at a specific threshold in DHM values, relative patterns through time were used to give context to recent levels of stress within each region.



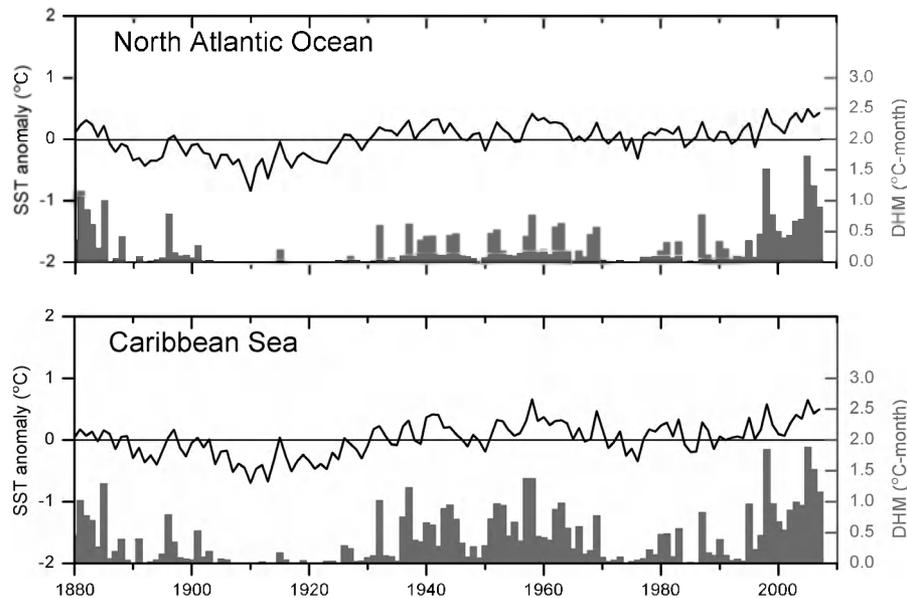
Sea surface temperature anomalies (SSTA) around reefs in the Indian Ocean (IO) region have increased through the 20<sup>th</sup> century by 0.50°C/century in Middle East and Western IO and by 0.59°C/century in Central and Eastern IO, with higher variability in the latter region (methods below). The temperature change in the Central and Eastern IO was faster than that of any other region. Throughout the IO, the highest anomaly occurred in 1998 and corresponded to the highest accumulated thermal stress (Degree-Heating-Months or DHM; defined below); 1998 was the El Niño year when widespread coral bleaching occurred across the entire Indian Ocean. The next two highest DHM values were in 2003 and 2005 for both regions, which typifies the steady increase in DHM through the 1990s. The Middle East and Western IO regions experienced a significant warm anomaly during the early 1940s, comparable to the highest SSTA observed in recent years, however, the accumulated thermal stress was considerably lower indicating that summer temperatures were not extreme. There was also a period in the late 1800s where thermal stress accumulated in the Central and Eastern IO despite having cooler than average annual SSTA values. This suggests that there was significant intra-annual variability within each of these years including unusually warm summers. A rapid rise from a cool winter into the warm summer temperatures, as likely occurred during the late 1800s, may have caused considerable stress in this region, however, temperature data prior to 1910 are sparse and therefore may not be reliable.



Reef locations in South-east Asia have also experienced increased temperatures during the last 80–90 years at a rate of 0.44°C/century with relatively small variability. This gradual rise correlates with a pattern of accumulating thermal stress that coincides with increased observations of bleaching. The year 1998 stands out for this region in both the SSTA and DHM, consistent with the most extensive bleaching. In contrast, there has been no particular stand-out year for the Great Barrier Reef and Warm Pool region but both temperature and accumulated thermal stress have been high since 1995. This recent episode of increased DHM may be related to a phase shift of the Pacific Decadal Oscillation (PDO) which has a periodicity of 50–60 years. The high variability of reef temperatures in this region is probably related to phases of El Niño and La Niña, however, there is still a general increase in thermal stress associated with the trend in SSTA values of 0.52°C/century. Coral bleaching was observed on parts of the Great Barrier Reef in 1998, 2002 and 2006.



The smallest temperature variability of all the regions was shown by reefs in the Western and Central Pacific Ocean (PO) with increasing trends in temperature of 0.40 and 0.35°C/century, respectively. Accumulated thermal stress increased slightly in both regions, however, the change in DHM levels appears to have remained fairly small. The consistency of DHM values since 1995, particularly in the Western PO, supports the suggestion of PDO influence. The Eastern PO shows much higher variability in temperature, characteristic of locations strongly influenced by El Niño-La Niña variations. The Eastern Pacific had the lowest increasing trend (0.24 °C/century). El Niño-Southern Oscillation events of 1982–1983 and 1997–1998 stand out in the SSTA and DHM traces. Levels of accumulated thermal stress are also highly variable throughout the record; corals that have lived through such variations may be well equipped to survive future stress events predicted with continued climate change. However, species diversity in the Eastern PO is low relative to more-stable regions. The highest bleaching and mortality in this region occurred in 1983 and was quite severe at many sites.



A feature of North Atlantic Ocean and Caribbean Sea records is the 65–70 year cycle of both temperature and thermal stress. The Atlantic Multi-decadal Oscillation (AMO) has a period of 65–70 years and clearly influences the pattern of temperatures on Atlantic and Caribbean reefs. This oscillating pattern is superimposed over the increasing temperature trends of 0.36 and 0.37°C/century for the North Atlantic Ocean and Caribbean Sea respectively. Although these are independent factors, when the warm phase of the oscillation is added to the steady increase in sea surface temperatures there is potential for serious consequences to coral reef ecosystems. The extensive and devastating bleaching during 2005 likely provides a foretaste of future bleaching events which could overwhelm many reefs in these regions.

## CONCLUSIONS

Water temperatures over the past century have risen on coral reefs in all global regions. The largest increases have been in the Indian Ocean, symbolised by the massive coral bleaching there in 1998. Thermal stress records show a high degree of correlation with widespread and severe coral bleaching observed on coral reefs around the world in recent years. Moreover, with predictions of continued warming, the outlook for corals around the world is one of repeated large-scale bleaching events. The question that remains is how successfully corals and reef ecosystems can acclimate and adapt to these future warm conditions.

## AUTHOR CONTACTS

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*The manuscript contents are solely the opinions of the authors and do not constitute a statement of policy, decision, or position on behalf of NOAA or the US Government.*

## 2. NEW CORAL REEF INITIATIVES

The sections below contain essays and opinion pieces that cover many of the emerging initiatives, programs and activities on coral reef monitoring, research, management and conservation.

### STATUS OF SOCIOECONOMIC FACTORS IMPACTING CORAL REEFS

CHRISTY LOPER AND RON VAVE

This Status 2008 report contains some good news (new large areas coming under protection and new regional initiatives to create MPA networks) and some bad news (continued degradation of coral reefs and poor or slow recovery from bleaching events in some areas) on the status of coral reefs around the world; both have real impacts on human inhabitants of the world's tropical coasts.

It is clear that declining quality of coral reefs negatively impacts those communities dependent on coral reefs for food, income, and revenue from tourism. However, coral reef conservation initiatives such as the Micronesia Challenge, the Caribbean Challenge, the Coral Triangle Initiative, and the Indian Ocean Challenge will provide the opportunity to better understand the impacts of developing MPAs on livelihoods of people, both positively and negatively. MPAs have been shown to bring positive consequences for the livelihoods of local people in the long-term; however, it should be recognised that there are often negative impacts on some sectors of the local populations in the short-term. These include the loss of habitual fishing grounds or increased risk of peril from travelling further to access alternative fishing grounds. Socioeconomic monitoring is needed to understand these impacts and mitigate negative effects where needed, such as provision of alternative livelihoods, and assist in accentuating the positive benefits.

Since Status 2004 socioeconomic monitoring in coral reef areas has increased exponentially through the GCRMN. A number of events have contributed to this increase:

- 2000: publication of the GCRMN *Socioeconomic Manual for Coral Reef Management*;
- 2002: formation of the Global Socioeconomic Monitoring Initiative for Coastal Management (SocMon), which serves as the socioeconomic monitoring arm of the GCRMN;
- 2003: publication of SocMon Regional Guidelines for the Caribbean and South-east Asia, and initiation of NOAA International Coral Grants for socioeconomic monitoring;
- 2004: translation of the Caribbean Guidelines into Spanish, and translation of the South-east Asia Guidelines into Tagalog (Philippines) and Vietnamese;

2006: publication of the Western Indian Ocean SocMon Guidelines and translation into French, Kiswahili, and Portuguese; and

2008: publication of SEM-Pasifika (SocMon Pacific) Guidelines and South Asia Guidelines

As a result, there are now 6 regions throughout the world successfully conducting socioeconomic monitoring through the SocMon Initiative: the wider Caribbean; Central America; South-east Asia; Western Indian Ocean; Pacific Islands; and South Asia. In some regions, initiatives other than SocMon have provided the bulk of socioeconomic monitoring data, such as the Locally Managed Marine Areas (LMMA) network which operates throughout the Pacific and in parts of South-east Asia. LMMA has conducted full socioeconomic monitoring at 49 of their 342 sites. Concurrent with this report the GCRMN Global Socioeconomic Monitoring Initiative, with funding from Conservation International's Marine Managed Areas Science Program, has prepared a report on the status of socioeconomic factors affecting coral reefs which includes an analysis of all SocMon data collected to date. This report is now available at [www.reefbase.org/socmon](http://www.reefbase.org/socmon). The major findings from this report include:

- In **South-east Asia** more than half the local communities surveyed are heavily dependent on fishing as their primary source of income, underscoring the need for healthy coral reefs and associated fisheries. Destructive fishing methods, such as cyanide and bomb fishing, are perceived as the most prevalent threats to the health of coral reefs and fisheries in the region, indicating that efforts to eradicate these methods, while effective in some regions (based on anecdotal evidence), should be increased to ensure food security and sustainable livelihoods for all coral-reef dependent communities.
- In the **Caribbean**, about one-third of surveyed local communities are dependent on fishing; however, SocMon data indicate that tourism is rapidly changing local communities. Tourism is also heavily dependent on healthy coral reefs, and is replacing fishing as the most important source of income for many communities and is seen as a viable alternative livelihood to fishing. Most communities welcome tourism development for revenue generation, however, many are also expressing concern over negative impacts of tourism on their way of life.
- In the **Pacific**, **LMMA** data from 29 villages in Fiji indicate that most households in each village harvest marine resources on a small-scale for subsistence and sell some excess. Commercial fishers comprise only a small portion of each village. The major threats to fishing grounds as noted from village management plans include over-fishing (resulting in the rare to non sighting of certain fish and invertebrates), garbage or pollution washing into the sea or along the coast, sedimentation from logging and forest clearing, and poor farming practices. Poaching in MPAs is also a problem indicating the need for greater commitment to, and logistics for, the enforcement of MPA regulations.

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## SYNOPSIS OF CONCLUSIONS OF THE 11<sup>TH</sup> INTERNATIONAL CORAL REEF SYMPOSIUM

RICHARD DODGE AND RICHARD ARONSON

At the 11<sup>th</sup> International Coral Reef Symposium, attended by 3500 leading coral reef scientists and managers, a recurring theme was the discouraging future of coral reef ecosystems. Climate change is proceeding much faster than in previous ice-age transitions, with coral reefs predicted to suffer extremely high temperatures and rising ocean acidification, and corals may not be able to keep up with these changes. There is no simple, silver-bullet remedy, nevertheless, we should not despair. Reefs can respond vigorously to protective measures and alleviation of stress and many scientific discoveries were presented that explained reef function with clues for remediation. Concerned scientists, managers, conservationists, stakeholders, students and citizens were called on to recognize extreme climate change threats to the world's ecosystems and demand urgent action to reduce CO<sub>2</sub> emissions. In the interim we can and must buy time for coral reefs by protecting them from sewage, sediment, pollutants, over-fishing, development and other stressors.

**Global Climate Change and Coral Reefs:** Scientists emphasized the major consequences of increasing greenhouse-gas-induced climate change:

- more coral bleaching from warmer oceans;
- rising ocean acidification from more dissolved CO<sub>2</sub>;
- more severe storms; and
- rising sea levels that will drown some coral-reefs.

National Oceanic and Atmospheric Administration (USA) satellites reveal that tropical oceans have warmed significantly faster during the last 10 years than previously. At this rate of change, only 8–10 years remain before CO<sub>2</sub> concentrations are predicted to exceed 450 ppm in the atmosphere. The extra CO<sub>2</sub> dissolving in seawater will threaten the existence of coral reefs as we know due to rising acidification. One third of the world's coral species are at high risk of extinction following widespread losses since the 1970s, with climate change as the major driver. Healthy and resilient coral reefs can respond robustly to damage but climate change stresses are eroding that resilience.

There is increasing evidence of changes in coral and fish community dynamics due to climate change. Corals are not recovering after devastation in many locations resulting in cascades of decreasing fish abundance and diversity. Ocean acidification is the 'evil twin' of global warming, because more CO<sub>2</sub> dissolving in the oceans is lowering pH and carbonate ion concentration. Coral reefs are particularly threatened because carbonate ions are essential for calcium carbonate skeletons, and lowered pH reduces resistance to erosion. Ocean acidification will prevent juvenile corals from settling and make adults more fragile. Coral reefs in more acidic eastern Pacific waters already have weaker calcium carbonate 'cement' and higher erosion rates. Acidification also slows the growth of corals and coralline algae, taxa that are vital to the geologic structure of reefs. There will be some 'winners and losers' in warmer and more acidic oceans, but nothing will be static and normal interactions between coral reef species will be perturbed.

**Other Scientific Advances:** Genetic studies are showing connections of reef organisms at scales from metres to ocean basins. Short-distance connections are the norm, with only occasional pulses of larvae connecting reefs at scales of thousands of kilometres. Many coral and fish larvae settle close to their parents, including fish larvae that return to local coral heads after travelling tens of kilometres. Genes within certain symbiotic zooxanthellae can make some corals more resistant to temperature extremes and bleaching by tolerating higher temperatures or producing chemicals to soak up toxic oxygen products. Corals that thrive at extreme temperatures (e.g. in tidal pools and enclosed seas) may have already selected temperature resistant symbiotic algae. Hence, some corals can cope with rising temperatures, and managers should consider designing networks of protected areas to incorporate such resistant species. Genes also code for signals that tell some corals when to spawn, ensuring synchronised activity. It is becoming increasingly clear that the role of microbes is important in nutrient cycles, in responding to climate change, and in disease. Some coral reef organisms also show increased immunity to disease.

**The Role of Science in Coral Reef Management:** Problems for reef managers are increasing as 50% of the world's population will live along coasts by 2015, putting unsustainable pressures on coastal resources, including the serial depletion of fish stocks in many poor countries. Major losses of coral cover have occurred in the wider Caribbean, South-east Asia, and Eastern Africa; however, many reefs remote from human pressures remain healthy — in Bermuda, Samoa, Fiji, Palau, French Polynesia, the Andaman Sea islands, Chagos and the Maldives. Some were devastated during the major bleaching event in 1998 and have demonstrated resilience with healthy and rapid recovery. Recovery has been ponderous or stalled on other reefs under chronic stress from agricultural runoff, other land-based sources of pollution, over-fishing, and habitat destruction from unsustainable coastal development. Reefs of the future will likely contain less attractive but tougher corals.

A key action for reef conservation is to evaluate reef-ecosystem goods and services to demonstrate that conservation is aligned with economic benefits, incentives, and cultural values. Improving reef management will require greater understanding of human behaviour toward reefs, poverty alleviation, global demand for fish products, and tourism. The goal is to avoid the 'Tragedy of the Commons.'

'Healthy Reefs for Healthy People' is a useful theme to link tourism, livelihoods, food security, and cultural and spiritual well-being and ensure that conservation is a partnership between all stakeholders. Marine protected areas will require a mix of organizational and scientific capacity to design no-take and periodically closed combinations that address community economic needs and conservation objectives. Natural and social scientists, managers and local communities must work cooperatively to reduce human stresses at local to global scales. Effective management rooted in solid, interdisciplinary science and coupled with stakeholder buy-in will give reefs a chance to survive.

**More ICRS Outcome Information:** [www.nova.edu/ncri/11icrs/outcomes.html](http://www.nova.edu/ncri/11icrs/outcomes.html)

Call to action: [www.nova.edu/ncri/11icrs/calltoaction.html](http://www.nova.edu/ncri/11icrs/calltoaction.html); sign petition at: [www.thepetitionsite.com/1/11th-international-coral-reef-symposium-call-to-action](http://www.thepetitionsite.com/1/11th-international-coral-reef-symposium-call-to-action)

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## CRISP AND CORAL REEF CONSERVATION IN THE PACIFIC

The Coral Reef InitiativeS in the Pacific program is implemented by 18 technical agencies (including SPREP, SPC and USP) with projects in 17 countries (including 3 French Overseas Territories) to improve the capacity to manage coral reefs sustainably for the benefit of Pacific people. The initial basis was French seed funding of 6 million euros, complemented by another EUR2.5 m (mainly from Conservation International, WWF and the United Nations Foundation). Implementation of on-the-ground action generated another EUR6.5 m through new partnerships in innovative and collaborative solutions. The external mid-term review in April 2008 concluded that significant progresses had been achieved since 2005 on: improving scientific knowledge and applied management of coral reefs; developing sustainable alternative income generating activities; expanding coral reef monitoring by supporting GCRMN; widely disseminating the lessons learned; training of students and technical people; raising awareness amongst stakeholders and users; and developing and strengthening networks. CRISP benefits from having two very experienced scientific advisers, Bernard Salvat of Ecole Pratique des Hautes Etudes in France and Clive Wilkinson at the Reef and Rainforest Research Centre in Australia, who assist in selecting research and application themes, monitoring research quality and helping to promote CRISP success at international levels. Since starting, there have been at least 12 peer review publications including one in 'Science'.

The CRISP program has assisted in establishing 30 MPAs in 12 different countries including the largest in the world, PIPA (see Box p. 195), and cooperating with the Locally Marine Managed Area network to promote community-based management at the scale of small island economies. A key theme is developing eco-regional analyses as models for integrated catchment and coastal management, and assessing the effectiveness of using transplant methods for reef restoration. A manual has been published in partnership with the World Bank Coral Reef Targeted Research project. Success has been achieved in developing sustainable fisheries markets based on cultured reef fish larvae for reseeded depleted lagoons, cage culture farming and supplying lucrative aquarium markets. Many invertebrates have been collected in the search for bioactive compounds with some showing strong pharmaceutical potential. The dissemination of knowledge and lessons learned is proceeding through development of an internet site [www.crisponline.net](http://www.crisponline.net), supporting ReefBase Pacific <http://pacific.reefbase.org>, and presenting results at international conferences. An 'Atlas of Coral Reefs' for 22 Pacific countries with GIS layers, will be funded by CRISP and put on ReefBase for free access.

CRISP has been a major supporter of GCRMN nodes in Polynesia and the South-west Pacific, and hence in the production of this Status 2008 report. This support has involved considerable training in field monitoring and laboratory data analysis, as well as providing high technology temperature, tide and wave recorders to assess climate change in 4 East Pacific countries. A special focus has been on providing tools to assess the economic value of coral reefs and MPAs to user communities : a set of guidelines will be produced as valid economic data are invaluable for convincing decision makers of the need for effective coral reef management (from Eric Clua, Coordinator of CRISP, [eric@spc.int](mailto:eric@spc.int)).

## **CORDIO: COASTAL OCEANS RESEARCH AND DEVELOPMENT IN THE INDIAN OCEAN STATUS REPORT 2008**

JERKER TAMELANDER AND DAVID OBURA

CORDIO is a research-based network that started in 1999 to support monitoring, research and capacity building for sustainable use and protection of marine environments following the 1998 mass coral bleaching and mortality in the Indian Ocean. After the Indian Ocean tsunami in 2004, CORDIO expanded geographically, as well as thematically, to assess vulnerability and adaptation of ecosystems and dependent communities with a strong focus on climate change. CORDIO works through a network of government agencies, NGOs, CBOs (community-based organisations) and the private sector, in close partnership with IUCN, to support conservation of biodiversity and sustainable use by working towards: (1) sustaining research on coastal and ocean ecosystems relevant to conserving and sustaining ecosystem function, goods and services; (2) strengthening social and economic assessment and research for integrated coastal management processes; (3) improving the livelihoods and well-being of coastal populations; (4) improving policies and the use of scientific and technical information in local, national and regional policy; (5) building capacity to meet objectives 1–4; and (6) fostering the networking and integration of science, management and policy.

CORDIO released its 5<sup>th</sup> Status Report in October 2008 (following reports in 1999, 2000, 2002 and 2005). It includes 45 papers from more than 100 authors, and presents new information on reef fish spawning aggregations, coral reproductive patterns and zooxanthellae dynamics; artisanal fishing around the Indian Ocean; on-going reef management initiatives; and priority setting (some parts are summarised below, pages 91, 105 and 119). The report alerts the reader to the immense changes that ecosystems and people are facing, and the urgent need for effective responses to combat climate change. It also identifies effective remedial activities and charts a course for CORDIO for the next decade. Notably, it reports encouraging reef recovery from the mass-mortality in 1998, especially in areas where there are low levels of human stress, illustrating that stressed reefs can rebound if pressures are effectively removed. This has implications for climate change adaptation planning, because reefs with fewer stresses will have more chance of adapting to a changing climate, and CORDIO, IUCN and other agencies are increasingly focused on applying resilience principles in reef management. Similarly, the welfare of coastal communities dependent on natural resources can be better addressed through improving information on socioeconomic status and trends; thus CORDIO and partners have developed socioeconomic monitoring manuals for the Indian Ocean (GCRMN SocMon) and tools to facilitate livelihood changes.

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## GEF-WB CORAL REEF TARGETED RESEARCH PROJECT

The Coral Reef Targeted Research and Capacity Building for Management (CRTR) Program is a global partnership supported by the Global Environment Facility, the World Bank Development Grant Facility (DGF), the University of Queensland (UQ), and NOAA USA, to address key knowledge gaps in our understanding of how coral reef ecosystems respond to global change and provide this information for decision-makers to promote needed actions for sustainable reef conservation. CRTR is a three-phase initiative that: 1) lays the scientific foundation for improved management interventions; 2) builds capacity to carry out adaptive research and management in key coral reef regions; and 3) works to integrate findings into management and policy at local, regional and international levels.

The CRTR Program is nearing the end of the first 5-year phase. The achievements to date include: a robust research program involving international teams of scientists being implemented in 4 Centers of Excellence in Mexico, Philippines, Tanzania and Australia; assisting with more than 200 hundred peer reviewed articles, including in CRTR, 'Science' and 'Nature', that have advanced our knowledge on how coral reefs respond to climate change and local stresses; new tools have been developed for managers and decision makers to assess threats to reefs and to design remedial action, including remote sensing tools to predict coral bleaching from temperature and solar insolation; a coral disease handbook with underwater cards to identify diseases, coral reef restoration guidelines for cost effective reef rehabilitation (with CRISP); and modelling and decision support tools to help stakeholders visualize impacts of resource use and policy decisions affecting coral reefs.

A future leader's network of 50 young scientists from the developing world have graduate scholarships to assist in building south-south collaboration. They made a strong showing at the 11<sup>th</sup> International Coral Reef Symposium in July 2008 as a demonstration of the effectiveness of this initiative. The CRTR Program has helped link research results to good management through Local Government Initiatives in the Centers of Excellence, especially in working with local mayors, local government officials, NGOs and tourism and fisheries representatives.

The Program has promoted the use of information to convince decision-makers of 'win-win' action with measures to improve coral reef health, also improving benefits to local communities from reef goods and services. The first phase has concentrated on building capacity for targeted research on coral reefs; the second phase of the CRTR Program will focus research efforts around 2 or 3 key questions on the future productivity of coral reefs with increasing CO<sub>2</sub> concentrations, soaring ocean temperatures, population pressures and globalization all threatening the very existence of coral dominated reefs. How and where we need to intervene to prevent the collapse of coral reefs will be a major thrust of this effort (from Ove Hoegh-Guldberg, Centre for Marine Studies, University of Queensland, Oveh@uq.edu.au; Marea Hatzioles Environment Department, the World Bank, Mhatziolos@worldbank.org).

## THE MICRONESIA CHALLENGE TO CONSERVE BIODIVERSITY

On 5 November 2005, the President of Palau, Tommy E. Remengesau Jr., called on leaders of the Federated States of Micronesia, the Marshall Islands, Guam and the Commonwealth of the Northern Mariana Islands to join in effectively conserving at least 30% of their nearshore marine resources and 20% of terrestrial resources by 2020. The President said “To address the islands’ unique biodiversity challenges, we need a unique approach and unique response. The Micronesian Challenge is our shared response.” The Challenge recognized the calls for major increases in conservation at the 2002 Johannesburg World Summit on Sustainable Development, as well as the Convention on Biological Diversity (CBD) 2004 Plan of Work on Protected Areas. These island states border the Coral Triangle of Southeast Asia and the Western Pacific and contain more than 61% of the world’s coral species, more than 13 000 species of reef fishes, 85 species of birds and 1 400 species of plants. But the Challenge also recognises that Micronesian biodiversity resources form the basis of the economy and cultures of the region, as well as being essential for the conservation of global biodiversity.

These leaders launched the Challenge at the 8<sup>th</sup> Conference of the Parties to the CBD in Brazil in 2006, as a part of the Global Island Partnership (GLISPA), which aims to increase island conservation through collaboration among all island partners. This massive task now falls to government and local NGO resource managers working with local communities, assisted by the Micronesia Conservation Trust, The Nature Conservancy, Conservation International, NOAA, DOI, USDA, SPREP, Pacific Islands Forum Secretariat, Rare International, the LMMA, and the Community Conservation Network. Together, the Nature Conservancy and Conservation International have pledged \$6 million (USD) toward an endowment to support management and enforcement mechanisms for new MPAs, and the Global Environment Facility has matched that pledge with another \$6 million. Thus the Micronesia Challenge is effectively a gift to the world.

The following strategies to implement the Challenge have been identified:

- Identify where the biodiversity is greatest and include these sites in protected area networks;
- Develop strategies to abate the biggest threats (pollution, deforestation, unsustainable fishing and invasive species) ;
- Incorporate climate change resilience into protected area network design;
- Raise awareness and support within local communities and organizations to increase protection of their coastal areas; and
- Encourage more funding in government budgets and develop income-generating mechanisms for biodiversity conservation.

Some examples of how the Challenge is being implemented include:

- New legislation in Palau to create a Protected Areas Network (PAN) with the Lake Ngardok Reserve (which includes the largest natural lake in Micronesia and is a major source of drinking water for Melekeok, the capital of Palau), as the first site;
- Creation of the Nimpal Channel Marine Conservation Area via a MOU between 2 Yap communities, supported by the State government, to sustainably manage their marine resources.

The Micronesia Challenge will boost coral reef protection and helped inspire the Caribbean Challenge (Box p. 280). However, more than \$100 million will be needed to complete this Challenge, which also depends on the world tackling global climate change with concrete action.

## MARINE PROTECTED AREAS: BIGGER, BETTER AND NETWORKED

Marine Protected Areas are regarded as the best strategy to conserve coral reef habitats and their biodiversity. This is elegantly spelt out in a recent (and somewhat depressing) book by Callum Roberts. Until recently, the only large coral reef MPA was the Great Barrier Reef Marine Park, established in 1975 with a marine area of 344,400 km<sup>2</sup>. Until recently, it contained less than 5% of the area under highly protected status i.e. no-take. The Park was re-zoned in 2004 to increase the no-take area to 33.5%, bringing the total no-take area within the Park to 115,395 km<sup>2</sup>. Then in 2006, 2 more large no-take MPAs were declared:

- The Papahānaumokuākea Marine National Monument was upgraded to no-take status from the original 356,893km<sup>2</sup> Northwestern Hawaiian Islands Coral Reef Ecosystem Reserve that had been designated in 2000.
- The Phoenix Islands Protected Area (PIPA) was declared by the Government of Kiribati with the assistance of Conservation International and The New England Aquarium in 2007. This now covers 184,700 km<sup>2</sup>.

MPAs are internationally recognised as the best way to conserve coral reefs. At the Johannesburg World Summit on Sustainable Development in 2002, there was an international commitment to establish many more MPAs in a representative global network. A year later, the IUCN World Parks Congress endorsed this and went further by recommending that at least 20–30% of each habitat be conserved in MPAs by 2012. Even further still, the Convention on Biological Diversity stated that 10% of each of the world's ecological regions, and that included marine and coastal areas, be effectively conserved by 2010. These calls were in support of the Johannesburg request to the CBD to reduce the rate of loss of biodiversity in the world by 2010.

However, a recent report detailed that only 0.65% of the world's oceans and 1.6% of marine areas inside Exclusive Economic Zones are currently protected; and the level of no-take protection is much less (0.08% of the world's oceans). The current rate of increase in these low numbers is less than 5%; thus the 10–30% targets will not be met for at least 20 to 30 years, rather than in the next 4 to 5 years. Therefore attention should be focused on rapidly increasing the amount of the world's ocean put under effective protection. The approach by The Pew Charitable Trusts will go a long way to bridging the gap. The Pew Environment Group has called for the establishment of very large no-take marine reserves and is actively working on: the Coral Sea waters of Australia (1 million km<sup>2</sup>); waters around the far north of the Northern Mariana Islands (300 000 km<sup>2</sup>); the Chagos Archipelago in the Indian Ocean (550 000 km<sup>2</sup>); and the Kermadec Trench off north-east New Zealand (600 000 km<sup>2</sup>). The 2002–2003 targets will only be met if the world community takes urgent and bold action to conserve very large areas of our natural heritage in the ocean.

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## STATUS OF FISH SPAWNING AGGREGATIONS OF THE WORLD

MARTIN RUSSELL, YVONNE SADOVY DE MITCHESON, ANDREW CORNISH,  
MICHAEL DOMEIER, PATRICK COLIN, AND KENYON LINDEMAN

Only a few of the known fish spawning aggregations (FSAs) are protected whereas more than three quarters show declining fisheries catches. In the Indo-Pacific, almost half of the known aggregations are either in decline or can no longer be found (possibly functionally extinct) and in the wider Caribbean (tropical western Atlantic), more than half of known aggregations have declined or are gone. These data are contained in the Society for the Conservation of Reef Fish Aggregations (SCRFA) online database.

Many coral reef fishes periodically and predictably aggregate to spawn, making them vulnerable to fishing. This occurs frequently when fishers discover an aggregation and find that large catches can be made easily. The problem for management is that little is known of aggregating fish behaviour and the impacts of fishing, although there is clear evidence of serious declines in several species, e.g. Nassau grouper. There has been a progressive increase in the discovery of aggregations globally but exploitation levels are largely undocumented. SCRFA seeks to rectify this through developing a global web-based database on FSAs. To date, 67 species in 9 fish families are known to aggregate to spawn in 29 countries or territories. Fishing pressure on spawning aggregations is increasing worldwide, but there is little effective management, and most species are now declining. Nonetheless, there are a few success stories demonstrating the benefits of aggregation management. Until recently, aggregations were seen as an opportunity for easy exploitation: now they are becoming known for their importance in the life-history of fish species and urgent management is needed.

Aggregation records held by SCRFA indicate that 79% of aggregations show clear evidence of declining catch landings. Of known Indo-Pacific aggregations 44% are either in decline or no longer exist (thus probably locally 'extinct'). In the wider Caribbean 54% of aggregations have declined or been eliminated with just a few sites where aggregations are stable or increasing; there are no data on many aggregations. So far, of the 55 aggregations under active protection, 19 (34%) of these are declining, 4 (7%) are considered to be lost, 5 (9%) are unchanged, fish populations are increasing at 2 (3%) sites; no data are available on 25 aggregations. Few aggregations are protected. Many coral reef fisheries management and conservation initiatives involve banning the sale of fishes during the spawning season or introducing seasonal or spatial closures. Catch quotas, limited entry, or fishing-gear controls are not commonly used.

Many fish species, including commercial species, aggregate to spawn but there are major differences between these species: wide variations in the numbers of fish assembling, differences in the distances travelled to the aggregation sites, and timings. Most records of aggregations are for groupers (*Serranidae*) and snappers (*Lutjanidae*). In some areas whole fishing communities target groupers, milkfish (*Channidae*), bonefish (*Albulidae*), rabbitfishes (*Siganidae*) and mullets (*Mugilidae*), which constitute much of the annual landings. Some grouper species such as *Epinephelus polyphkadion* are rarely caught at other times of the year.

The majority of research and monitoring of aggregations occurs in the wider Caribbean whereas little is known about aggregations in the Indo-Pacific. There is a similarity in the nature of most aggregation sites globally; most common are reef passes, channels, promontories, and outer reef-slope drop-offs. Most fish are caught with hook and line, and spears. Traps are used in the Caribbean and Indian Ocean, and gill nets and cyanide are being used in Indonesia and the Philippines.

Until recently, many exploited aggregations continued to produce good landings. Some sites were fished for subsistence for more than 70 years but when fishing intensified rapid declines in the abundance and size of fish populations were reported. For example, catch rates in Palau exceeded one ton of grouper per boat trip in the 1960s; by the 1980s and 1990s catch rates had dropped to about 200 kg per boat trip, and now are even lower.

The Nassau grouper is a well known species threatened by aggregation fishing. Catch landings in major fishing areas in Cuba and the Bahamas were predominantly from aggregations. However, of at least 50 known aggregations, fewer than 20 remain today, with 100–3000 fishes at these sites, whereas there were tens of thousands of fish a few decades ago.

There is little information about the effectiveness of aggregation management, because there are few examples of recovering aggregations. Certainly, if management can permanently stop fishing at aggregation sites, there are clear benefits. One example is a large permanent no-take MPA created in the US Virgin Islands on an aggregation site which had previously been seasonally closed for 9 years. Within 3 years the estimated spawning population of the red hind (*Epinephelus guttatus*) increased threefold (from 26 200 to 84 000).

Significant challenges remain to achieve sustainable management of aggregations despite recent advances in our understanding and awareness. If exploitation of aggregations continues unchecked there will be severe consequences for the fishes and the people who rely on fishing for a livelihood. Healthy aggregations indicate healthy fisheries and the loss of an aggregation is an important indicator of poor fisheries management. In extreme cases aggregation fishing may threaten a targeted species, as in the case of the Nassau grouper, however, properly managed aggregations can be the source of important sustainable production.

The SCRFA spawning aggregation online database contains information on coral reef fish spawning aggregations and documents their current status, management and exploitation history. There are currently 560 records of tropical spawning aggregations in this open access database, [www.scrfa.org](http://www.scrfa.org). A username and password is needed to enter or edit data.

### **AUTHOR CONTACTS**

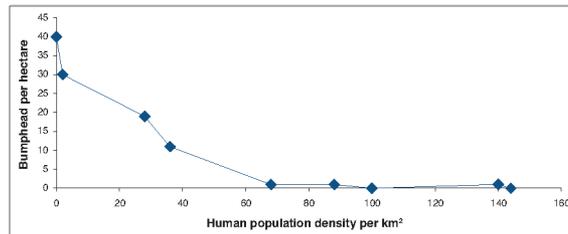
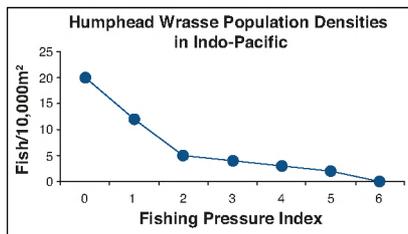
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## WHERE HAVE ALL THE BIG FISH GONE? FISHING REMOVED THEM BEFORE SCIENTISTS KNEW

Losses of large marine fishes are clearly happening on coral reefs around the world. Big fish at the top of the food chain, the apex predators, are selectively taken by fishers, especially cods, groupers, snappers, wrasses, sharks and large pelagic fish. This is called 'fishing down the food web' or 'serial depletion', because fishers normally start fishing the large, top predators, or highest value fish, and subsequently fish down through the food chain. A key example is the humphead wrasse (*Cheilinus undulatus*, also called Napoleon wrasse or Maori wrasse). This fish is the top target for the Asian live food fish trade, especially for Hong Kong where individuals can sell for up to US\$150 per kg in restaurants. Populations are highest on islands with little to no fishing or targeting (like Wake Island), and in effectively protected areas such as the Great Barrier Reef: populations decrease rapidly with increasing fishing pressure, as seen in parts of the Indo-Pacific.



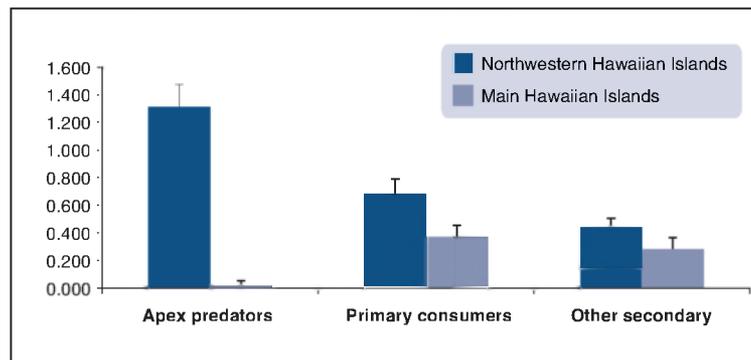
**The left graph, adapted from Sadovy et al. 2003, shows a major decline in humphead wrasse populations with increasing fishing pressure measured from 0 (virtually none); to 6 (extremely high fishing pressure); based on nearby population size, extent of fishing and level of protection. The graph on the right was adapted from Bellwood et al, 2003 and shows bumphead populations decrease rapidly as human population densities increase.**

Similarly, populations of the giant bumphead parrotfish (*Bolbometopon muricatum*) decrease with increasing human pressure: for example, they were once common on some Fijian islands and dominated the catch in the local fish markets, now they are rare or locally extinct. An analogous situation is occurring in the Solomon Islands where the fish are speared at night while they sleep in caves. The Nassau grouper (*Epinephelus striatus*) was once very abundant and regularly seen and caught on Caribbean reefs. These fish aggregate to spawn in large numbers but their distribution and population densities have dramatically declined in recent years due to over-fishing. Many countries have or are introducing drastic protection measures, such as area and seasonal closures, to try to prevent extinction.

Reef fish communities on unfished remote reefs in the Hawaiian and Line Islands retain what are probably near natural populations of big apex predatory fish, whereas these fish are virtually absent around populated, fished islands. Another example of big fish removal is by fishers targeting shark from the Great Barrier Reef for the Asian shark fin trade, and also selectively removing sharks to facilitate fishing for high value coral trout. Shark populations in no-take areas of the Great Barrier Reef Marine Park are much higher than on areas of the reef open to fishing, and similar to those in the unfished Cocos-Keeling Atoll. Black marlin are caught throughout the Pacific Ocean and aggregate to spawn on the Great Barrier Reef. World size and fishing tournament records for black marlin (*Makaira indica*) caught in the Pacific Ocean were mostly set many years ago. Even with

increasing fishing power by game boat fishing, the strike rates don't seem to be improving, rather staying constant, indicating a dramatic effect of fishing.

Few of the world's coral reefs still have good populations of large fish: this is in stark contrast to the majority of coral reefs that are heavily fished. Most scientists and fishers today have not seen pristine reefs with abundant large reef fish, so it's a common mistake to judge a fish population on recent observations rather than the true baseline. We unknowingly accept a shifted baseline. The removal of apex predators and other large fish is highly likely to have severe effects on the ecosystem. It is important to regularly assess the baseline we are using when reporting on the status of coral reefs. The remaining few pristine reefs are essential reference points for large reef fish (from Douglas Fenner, [dfenner@blueskynet.as](mailto:dfenner@blueskynet.as) and Martin Russell [Martin.Russell@gbrmpa.gov.au](mailto:Martin.Russell@gbrmpa.gov.au)).



*Here is clear evidence of fishing pressures on big fish. There are healthy populations of the large predatory fish on the remote and unpopulated coral reefs of the North-west Hawaiian Islands (the Papahānaumokuākea Marine National Monument), whereas apex predators are notably lower around the populated main Hawaiian Islands (from Friedlander and DeMartini, 2002).*

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## PROMOTING SUSTAINABLE TOURISM ALONG THE MESOAMERICAN REEF

A core strategy to improve reef health in the Mesoamerican Reef (MAR) region is to engage local communities whose livelihoods depend on healthy coral reefs. Since 2004 the Coral Reef Alliance (CORAL) has collaborated with local partners to improve environmental business practices and minimize coral reef damage by empowering the tourism sector as advocates for reef conservation. CORAL promotes conservation through the Coral Reef Sustainable Destination (CRSD) approach that combines MPA management and sustainable business options for community benefit. This approach harnesses community action to develop better business practices and marine conservation linked with alternative livelihoods, better fishing practices and preserved cultural identity. This follows the successful ICRAN Mesoamerican Reef Alliance project on sustainable marine tourism in Mexico, Belize and Honduras. MARTI (Mesoamerican Reef Tourism Initiative) is a collaboration between CORAL, Conservation International, Amigos de Sian Ka'an (a Mexican NGO), and hotels, marine recreation operators and cruise lines to reduce the tourism footprint while maximizing coral reef benefits through:

- **Environmental Performance Standards in the Marine Tourism Sector:** In 2007 collaboration was established among MAR marine tour operators and associations, park managers, local NGOs, cruise lines, government agencies, scientists and concerned divers to adopt voluntary environmental standards for scuba diving, snorkeling, and recreational boating. These successful region-wide standards have improved relations between the private sector and MPA managers and fostered cooperative partnerships between MPA managers and resource users to improve compliance with park regulations, increase operator education and training, and develop local conservation initiatives that leverage tourism as a force for conservation.
- **Institutionalizing the Reef Leadership Network Training Program:** Using CORAL's educational curriculum on reef conservation, resource management and sustainable tourism practices, MARTI created qualified and motivated leaders to provide educational outreach and disseminate best practice: these Reef Leaders teach workshops on sustainable recreation to hundreds of boat captains, tour guides and fishers.
- **Technical and Financial Assistance for Local Conservation Initiatives:** Throughout MAR, CORAL and MARTI facilitate unprecedented partnerships between local community members, government leaders and marine recreation providers through workshops that define project goals, identify key players, determine roles and responsibilities, and provide technical and financial assistance to local leaders. Successful initiatives since 2006 include: mooring buoy programs to reduce anchor damage at 120 sites; school education programs to train teachers and students in coral reef ecology, conservation and park infrastructure; and awareness programs to build capacity for effective management and improved community support for MPAs.
- **The Sustainable Marine Recreation Environmental Walk-Through (EWT) Program:** The voluntary standards project provides advice through MARTI to marine recreation providers to improve business practices and reduce ecosystem damage. Combining critical performance assessment with comprehensive recommendations for action, EWT covers company policies and management plans; staff training; effective management of tours and visitors; increasing environmental awareness among visitors; minimizing impacts; and contributing to reef conservation. The program currently engages many tour operations throughout Mexico, Belize, and Honduras to improve environmental performance. (Contact: Rick MacPherson, The Coral Reef Alliance, San Francisco, rmacpherson@coral.org; www.coral.org).

## THE CORAL TRIANGLE INITIATIVE: THE WORLD'S GREATEST CORAL REEF CHALLENGE



The Indonesian President, Susilo Bambang Yudhoyono, launched the Coral Triangle Initiative (CTI) with a formal letter to the Convention on Biological Diversity (CBD) Conference of the Parties in Brazil in 2006. He emphasised the critical need to protect the biodiversity within the Coral Triangle area as part of global efforts to reduce the loss of biodiversity. In August 2007, President Yudhoyono invited 7 regional and world leaders to sign onto the 'Coral Triangle Initiative on Coral Reefs, Fisheries, and Food Security' which aims to conserve these resources, and ensure the food security values of regional fisheries. The Initiative was officially launched with the support of 21 leaders at the Asia Pacific Economic Cooperation (APEC) summit in Sydney, September 2007. The Coral Triangle area includes the Exclusive Economic Zones of central and eastern Indonesia, Timor Leste, the Philippines, the Borneo part of Malaysia, Papua New Guinea and the Solomon Islands. Although this covers only 2% of the global ocean, the area is the 'hot spot' of global biodiversity with more than 75% of all coral species, 35% of the world's coral reefs, at least 3 000 fish species and the largest area of mangrove forests in the world. The Coral Triangle is also a major nursery area and migratory route for tuna and billfish, whales, dolphins, manta rays, whale sharks, dugong and many other marine mammals. These are major economic and social resources for the livelihoods of 120 million people in the area, with many depending almost entirely on these biodiversity resources. The area is also of major economic value for these countries from tuna fisheries and nature-based tourism, plus the mangroves and coral reefs protect sensitive coastlines from storm and tsunami damage. The estimated total annual value of the coral reefs is US\$2.3 billion for the region.

As the coral reefs have suffered considerable degradation due to pollution; over-fishing, including illegal and destructive fishing practices; unsustainable coastal development and deforestation; and climate change – all driven by the activities of large human populations – the CTI has established these main criteria for activities:

- Encouraging people-centered initiatives in biodiversity conservation, sustainable development, poverty reduction and equitable benefit sharing;

- Basing all conservation activities on reliable science;
- Focusing action on quantitative goals and timetables established at the highest political levels;
- Using existing and future forums to promote implementation;
- Aligning with international and regional commitments;
- Recognising the transboundary nature of many of these natural marine resources;
- Emphasising priority geographies;
- Engaging a diversity of stakeholders; and
- Recognising the uniqueness, fragility and vulnerability of island ecosystems.

The first major step will be to secure sustainable funding and develop a plan to ensure long-term funds with the possibility of using endowments, trust funds and national budgets e.g. through tourism fees or airport taxes. The CTI is currently being supported by the Global Environment Facility; Asian Development Bank; the Governments of USA and Australia; and through a unique partnership between 3 large NGOs, the World Wildlife Fund, the Nature Conservancy and Conservation International; with a current budget of approximately US\$300 million. The CTI countries will need the support of outside donors and agencies and success can only be assured if the world will seriously address the long-term threats posed by climate change.

### **DO REEF COMMUNITIES OF THE EASTERN TROPICAL PACIFIC EXIST AS ALTERNATIVE STABLE STATES?**

Coral reefs worldwide are undergoing rapid and dramatic transitions from coral to algal dominated states: scientists question whether these transitions represent alternative stable states. The Eastern Tropical Pacific is ideal to address this critical question as elevated temperatures during El Niño Southern Oscillation (ENSO) caused dramatic community shifts after bleaching and mortality of coral opened large areas for algae. Here we provide 3 lines of evidence that ENSO disturbances mediate transitions between alternative states. First, surveys established that hard substrates on reefs are almost always completely dominated by either coral or algae, with few areas in transition. Second, ecological processes stabilising the coral state include high herbivory rates, minimal response of algae to nutrients, rapid recovery toward coral domination and prolific asexual reproduction. Processes that stabilize the algal state include unstable habitat comprised of dead coral rubble, off reef refuges for opportunistic macro-algae, and positive associations with cyanobacteria. Third, macro-algal blooms were documented persisting over 5 years, encompassing many algal generations (one criterion for stability). Evidence that the reef-building coral state has persisted over millennia has been provided by Rich Aronson's push-core research. While the evidence above follows alternative stable state predictions, we cannot rule out that these reefs are undergoing slow, patchy succession: the only way to discern between the two possibilities is experimental. Alternative stable state theory predicts that development of either algal or coral states depends on the density of the initial colonizers: an experiment testing this effect has been set up to detect initial coral and algae trajectories (from Peggy Fong pfong@biology.ucla.edu; Tyler Smith tsmith@uvi.edu).

### 3. THE STATUS OF COLD-WATER CORAL COMMUNITIES OF THE WORLD: A BRIEF UPDATE

EDITED BY THOMAS F. HOURIGAN

WITH CONTRIBUTIONS FROM: JAMES BOUTILLIER,  
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J. MURRAY ROBERTS, DI TRACEY, STEFAN HAIN

#### INTRODUCTION

For the first time, in 2004 a chapter on 'Cold-water Coral Reefs' was included in the Status of Coral Reefs of the World reports. This reflected the rapidly increasing awareness of these communities as biologically diverse and fragile habitats vulnerable to human impacts. Since 2004, there has been a tremendous increase in research on, and action to protect, these cold-water counterparts to tropical coral reefs. This chapter updates recent discoveries and conservation efforts.

Cold-water corals, also called 'deep-sea' or 'deep-water' corals, are a taxonomically and morphologically diverse collection of organisms distinguished by their occurrence in deeper or colder oceanic waters. Such corals lack symbiotic algae (zooxanthellae) characteristic of most reef-building shallow water tropical corals, and generally grow much more slowly than tropical corals. The calcified skeletons of some branching stony coral species (e.g. *Lophelia pertusa*) can form large reefs in deep water, whereas others, including gorgonians and gold, black and stylasterid corals, do not form reefs, but occur either singly or in tree-like thickets ('coral gardens'). Both reefs and gardens provide habitats for many fishes and invertebrates and enhance the biological diversity of many deepwater ecosystems, similar to tropical coral reefs.

Cold-water coral assemblages are particularly vulnerable to damage from bottom trawling; thus most recent conservation efforts have focused on preventing fisheries damage. These unique communities may also be damaged by energy exploration and development, deployment of submarine cables and pipelines, and changes in water chemistry (e.g. ocean acidification due to climate change). Recovery may take decades to centuries as most cold-water corals grow slowly.

## RECENT DIRECTIONS IN SCIENCE, CONSERVATION AND MANAGEMENT

The proceedings of the 2<sup>nd</sup> and 3<sup>rd</sup> International Symposia on Deep-Sea Corals documented the acceleration in the study of these ecosystems and increasing emphasis on their protection and management. Much of the attention is focused in the North Atlantic, North-east Pacific and South-west Pacific; there is increasing recent interest in similar ecosystems near developing countries and small island developing states (SIDS) as well as on high seas seamounts.

Major international programs are expanding knowledge of cold-water coral ecosystems. The 'Hotspot Ecosystem Research on the Margins of European Seas' (HERMES) project ([www.eu-hermes.net](http://www.eu-hermes.net)) is an integrated pan-European project with 50 partners funded by the European Commission on cold-water coral reefs and other deep-sea habitats (e.g. cold seeps, anoxic environments, mounds, canyons and continental slopes), and has established strong links with European and global marine policy makers. HERMES will conclude in March 2009, with 'Hotspot Ecosystem Research and Man's Impact on European Seas' (HERMIONE) starting in April 2009. The Trans-Atlantic Coral Ecosystem Study (TRACES; [www.lophelia.org/traces](http://www.lophelia.org/traces)) will establish the first basin-scale study of cold-water coral ecosystems, and workshops in North America and Europe in 2008 developed the TRACES Science Plan. The Census of Marine Life ([www.coml.org/](http://www.coml.org/)) will also coordinate research and information on critical ecosystems including seamounts (CenSeam), the North Atlantic mid-ocean ridge (Mar-Eco) and continental margins (CoMarg-E).

Major international trends in cold-water coral activities since 2004 are expanding:

- Attention beyond cold-water stony coral 'reefs' to include other coral-dominated communities (coral gardens) because gorgonians and black corals are the dominant species in many regions and support diverse deep-sea communities. Some black and gold coral colonies can exceed 2000 years in age; probably the oldest living animals in the world;
- Appreciation of cold-water coral communities on seamounts as there are probably 100 000 seamounts which rise more than 1 km above the seabed: only 350 have been sampled. Most seamounts occur outside national jurisdiction which has stimulated interest in high seas conservation (see recent reviews below);
- Conservation from protecting individual cold-water coral reefs (e.g. efforts by Norway and Canada from 1999 to 2004) to addressing bottom-fishing impacts over larger regions (e.g. major efforts in the US North-east Pacific, 2006, and around New Zealand, 2007), with comprehensive conservation frameworks within Regional Fisheries Management Organizations and Agreements (RMFO/As).

## CONSERVATION OF COLD-WATER CORAL AND OTHER VULNERABLE ECOSYSTEMS

United Nations General Assembly (UNGA) resolutions from 2004 have addressed the damage to high-seas deep-sea fisheries on vulnerable marine ecosystems (VMEs), including seamounts, hydrothermal vents and cold-water corals. Most notably, the 2006 UNGA Sustainable Fisheries Resolution 61/105, called upon States, individually and through Regional Fisheries Management Organizations and Agreements (RFMO/As) to take actions to sustainably manage fish stocks and protect VMEs from destructive fishing practices, recognizing the immense importance and value of deep sea ecosystems and the biodiversity they contain. In 2008, the UN Food

and Agriculture Organization (FAO) adopted International Guidelines for Deep Sea Fisheries. RFMO/As are using these guidelines in their management efforts to fulfill the UNGA mandate (see the Table below). Also in 2008, the Convention on Biological Diversity (CBD) adopted 'Scientific Criteria for Identifying Ecologically or Biologically Significant Marine Areas in Need of Protection in Open-ocean Waters and Deep-sea Habitats,' which are applicable, and refer, to cold-water corals and other marine ecosystems that are vulnerable, fragile, sensitive, or slow to recover.

The following ocean basin summaries contain some of the new information on national and multilateral efforts to understand, conserve and manage cold-water coral ecosystems (there are no major cold-water coral communities known in the Arctic Ocean). Information from developing countries and the high seas, especially in the southern hemisphere, is scarce, indicating an urgent need for further research. This compilation is not exhaustive, particularly with regard to fishery measures in developing countries.

### ***Atlantic Ocean***

North Atlantic cold-water corals are among the best studied. The Northeast Atlantic Fisheries Commission (NEAFC) recommended measures to manage fisheries on the high seas in the North-east Atlantic and Arctic Oceans. NEAFC was the first RFMO to institute specific protections for cold-water coral areas, prohibiting bottom trawling and fishing with static gear on four seamounts and a section of the Mid-Atlantic Ridge in 2004. Additional areas were closed or modified in 2007 and 2008. The Northwest Atlantic Fishery Organization (NAFO) plays a similar role and in 2006 and 2008, NAFO closed 4 seamount areas to all bottom fishing until 2010, with an option for exploratory fishing based on scientific advice. NAFO and Canada created a Coral Protection Area closed to all bottom contact fishing for 2008–2012 in a continental slope area within Canada's Exclusive Economic Zone on the south-west Grand Banks. NEAFC and NAFO are soon expected to adopt comprehensive measures to address significant adverse impacts from fishing on VMEs.

The Southeast Atlantic Fishery Management Organization (SEAFO) manages bottom-fisheries in part of the South-east Atlantic high seas. In 2006 SEAFO identified 13 vulnerable areas (mostly seamounts) and closed 10 to all bottom-fishing for an interim period. The Central Atlantic and South-west Atlantic area is outside national jurisdictions and not currently covered by existing bottom-fishing RFMO(s); and none are under development.

**Europe and the North-east Atlantic:** The *Lophelia pertusa* reefs in the North-east Atlantic were among the first cold-water coral ecosystems to gain widespread scientific knowledge and conservation attention. Norway was the first country to protect these corals in European waters. Since 2004, research has continued under national and international programs, and protection efforts have accelerated.

Mapping of coral areas off Iceland was initiated in 2004, and 3 areas were protected in 2006. The Santa Maria di Leuca deep coral mounds, the only known large-scale *Lophelia* reefs in the Mediterranean, were protected in 2006, and in 2007 more of the Northwest Rockall Bank and Logachev Mounds protected from bottom-fishing. The OSPAR Commission for the Protection of the Marine Environment of the North-east Atlantic has identified conservation priorities in the North-east Atlantic and in 2008 the 'coral gardens' habitat was included among threatened

and declining species and habitats, thereby broadening the previous emphasis on *Lophelia* reefs. Also in 2008, OSPAR adopted a 'Code of Conduct for Responsible Marine Research in the Deep Seas and High Seas of the OSPAR Maritime Area', which includes scientific investigations.

**Canada – North-west Atlantic:** The Department of Fisheries and Oceans (DFO) and the Dalhousie and Memorial University of Newfoundland and Labrador have conducted surveys since 2006 on unexplored deep parts of the continental slope, including the North-east Channel Coral Conservation Area in the Discovery Corridor off south-west Nova Scotia, the Gully Marine Protected Area, Shortland Canyon, Haldimand Canyon and the *Lophelia* Conservation Area at the Stone Fence on the Scotian Slope, and Haddock Channel and Debarres Canyon on the south-west Grand Banks. These surveys have expanded species ranges, and recorded new taxa. Data are recorded in the ARCGIS database on corals and sponges, and habitat associations, combined with by-catch records from groundfish trawl surveys and fisheries observers on commercial vessels. Population genetic analyses, recruitment, growth, ageing and reproductive studies have also been initiated.

In May 2007 the Canadian offshore shrimp and groundfish trawling industry voluntarily closed fishing to protect cold-water corals off Baffin Island, Newfoundland and Labrador. The 12 500 km<sup>2</sup> coral protection zone contains gorgonian corals, and captains follow a code of conduct to stop fishing in areas they believe corals may exist, even outside the voluntary closure zones.

**United States – North-west Atlantic:** The US Congress amended the principal fisheries law in 2006, mandating a Deep Sea Coral Research and Technology Program and allowing protection of identified deep sea coral areas. In 2007 an assessment of cold-water coral ecosystems, *The State of Deep Coral Ecosystems of the United States*, was published. The US Atlantic has numerous cold-water coral habitats: gorgonians predominate in rocky areas in canyons in the north-east and the New England Seamount chain. The Oceanographer and Lydonia Canyons, including important cold-water habitats, were closed to fishing for monkfish in 2005. Reef-building cold-water corals, including *Lophelia pertusa*, reach their greatest abundance and development from Cape Hatteras to Florida. The South Atlantic Fishery Management Council is considering protecting several large Habitat Areas of Particular Concern. Reefs also occur in the Gulf of Mexico with abundant gorgonians and black corals; but these are poorly documented.

**Caribbean and South Atlantic:** The Caribbean contains structure-forming deep-water stony, black, and gorgonian corals, especially in Colombian waters. Information on cold-water coral ecosystems in the South Atlantic remains very sparse. Communities are dominated by *Lophelia pertusa* in the South-east Atlantic from the margin of the Angola shelf. *Lophelia pertusa* and *Solenosmilia variabilis* dominate cold-water reefs off the coast of Brazil and cold-water coral mounds have been found off the Patagonian shelf.

## ***Pacific Ocean***

There are extensive un-surveyed cold-water coral areas throughout the Pacific Ocean with the best studied areas being the North-east Pacific (rich gorgonian-dominated slopes and seamounts); the Hawaiian Archipelago and seamounts with harvested precious corals (but probably has no cold-water reefs); and seamounts in the South-west Pacific with rich octocorals and scleractinian reef-forming corals. It is probable that cold-water corals reach their highest

diversity in the Indo-Pacific, similar to tropical corals. There are no existing RFMO/As on bottom-fishing beyond areas of national jurisdiction in the Pacific. A South Pacific Fisheries Management Organisation (SPRFMO) is under development for the area from South America to eastern Australia; a similar body is under negotiation for the North-west Pacific. Interim conservation measures have been agreed for both areas in accordance with UNGA Resolution 61/105.

**Canada – Northeast Pacific:** Significant cold-water coral habitats exist in deeper waters along the Canadian Pacific coast, similar to those in US waters. Fisheries and Oceans Canada (DFO) has significantly increased the number of cold-water coral species to 80 off British Columbia during surveys on the continental slope from 500–2400 m in response to the expansion of new fisheries in these areas. DFO is drafting, consulting and implementing a Cold-water Coral and Sponge Conservation Strategy for the West Coast of Canada. In 2008 the Bowie Seamount 180 km west of Haida Gwaii (Queen Charlotte Islands) was declared Canada's 7<sup>th</sup> MPA. It comprises the Bowie, Hodgkins and Davidson seamounts of the Kodiak-Bowie seamount chain with an area of 6131 km<sup>2</sup>. The seamounts have not been fully explored, although many coral species occur there. The MPA regulations prohibit disturbance, damage, destruction or removal of any living marine organism, any part of its habitat or any part of the seabed, including the subsoil; fishing is prohibited in one zone and limited in other zones.

**United States – Pacific:** Cold-water corals are important structural components in the Gulf of Alaska and Aleutian Islands. U.S. cold-water gorgonians reach their highest diversity in the Aleutian Islands and often form complex 'coral gardens' with stylasterid corals, sponges, and other organisms. In 2006, measures to minimize the adverse effects of fishing on essential fish habitat closed over 980,000 km<sup>2</sup> to bottom trawling, thereby protecting important cold-water coral habitats on seamounts, continental slopes, and ocean ridges. More trawl closures were instituted in 2008 in the Bering Sea, where soft corals predominate.

The seafloor off Washington, Oregon, and California contains extensive coral communities as documented in trawl survey catch records, supplemented by museum collections and underwater vehicle exploration. In 2006, the U.S. implemented a comprehensive plan to protect essential fish habitat for groundfish, focusing largely on pristine or untrawled habitat and ecosystems such as cold-water corals. More than 336 700 km<sup>2</sup> were protected from bottom trawling, with selected areas (e.g. several seamounts) protected from all fishing gears that contact the bottom.

**Southeast Pacific:** There are few data on the cold-water coral fauna of the South-east Pacific: recent studies in Chile revealed large assemblages of black, gorgonian and stylasterid corals in the shallow-water fjords and bycatch of deeper-water corals in fisheries, including on O'Higgins Seamount.

**Australia – South-west Pacific:** In 2007 the Southeast Commonwealth Marine Reserve Network was approved, encompassing 13 zones with varying levels of protection from total fishing bans through to multiple-use reserves. This expands the Tasmanian Seamounts Marine Reserve to cover 220 000 km<sup>2</sup> of underwater canyons and seamounts. The objectives of the Network are to include representative areas of major seafloor features and fauna from the Great Australian Bight through Tasmanian waters to southern New South Wales. Some protected seamounts

were surveyed in 2007 and 2008 and confirmed the presence of cold-water corals and high biodiversity. The orange roughy fishery on the South Tasman Rise was closed by Australia and New Zealand in 2007. This region contained large quantities of coral (mainly *Solenosmilia variabilis*) in orange roughy bycatch.

**New Zealand – South-west Pacific:** The closure of 19 seamounts to all bottom trawling and dredging in 2001 was recently expanded with 17 new Benthic Protected Areas (BPAs) in the New Zealand EEZ. These areas cover 1 200 000 km<sup>2</sup>, about 30% of the EEZ: the network was proposed by the New Zealand fishing industry and adopted by the government in November 2007. The main objective was to protect pristine benthic ecosystems where there has been little or no fishing. The biota communities are poorly known, although cold-water reefs are present. The closures include many seamounts, including the 19 previously protected, and hydrothermal vents. Bottom trawling is banned and other contact operations are closely monitored by government observers. Outside the BPAs most bottom trawling is regulated solely by setting commercial fish species quotas but coral bycatch continues to be a concern in some areas where fishing has expanded to new grounds.

There has been continued research on the effects of trawling on seamounts especially the impacts on corals. Some seamount features are monitored off the east coast of New Zealand which clearly shows that corals are severely damaged by heavy ground gear of deepwater trawls. Some patches of reef remain on heavily fished seamounts where lava flows or rocky bottoms prevent trawling. There is evidence of recent stylasterid coral settlement on fished seamounts that were protected in 2001. Research has also continued on biodiversity (including taxonomy and at-sea identification), biogeography, growth and ageing, and invertebrate identification guides have been produced. Rapid Vulnerable Marine Ecosystem (VME) identification guides are being produced for use by observers in international waters of the South Pacific and Ross Sea.

### ***Indian Ocean***

Information is sparse on Indian Ocean cold-water coral communities. Cold-water scleractinian corals have been recorded within Indian waters and the Southwest Indian Ocean, but very few sites have been sampled and fewer protected. Trawl fisheries are likely causing damage to cold-water coral habitats. Southwest Indian Ocean orange roughy fisheries underwent rapid exploitation and decline from 1998 to 2003, and a similar pattern of bottom-trawl fisheries could threaten seamount ecosystems in the central-eastern southern Indian Ocean. Indian Ocean deep-sea fisheries are managed through the South Indian Ocean Fisheries Agreement, but there are no management measures to address the impacts of these fisheries on VMEs. In 2006, the Southern Indian Ocean Deepwater Fishers' Association voluntarily refrained from bottom-trawling in several Indian Ocean areas with cold-water corals.

### ***Southern Ocean***

The Southern Ocean surrounds Antarctica and the northern border is generally identified as the Antarctic Convergence (between 50°S to 60°S). The area is relatively depauperate in cold-water corals, but includes some structure-forming species in the best studied areas around the Antarctic Peninsula below South America, and south of Australia and New Zealand. The Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) is responsible for managing marine living resources in this region. In 2007, member States of CCAMLR

adopted comprehensive measures for all bottom fishing activities, requiring assessments by flag States and the CCAMLR Scientific Committee and biennial reviews to assess effectiveness of conservation.

## EMERGING ISSUES

The 2004, GCRMN report identified a number of potential threats to cold-water coral communities, including bottom trawling and other bottom fishing, hydrocarbon exploration and production, submarine cable and pipeline placement, bioprospecting and destructive scientific sampling, waste disposal, dumping and pollution, and coral exploitation and trade. Since then, there has been tremendous activity to address fishing impacts, however, there has been increased information on, and concern about, the potential future impacts of ocean acidification and seabed mining.

**Ocean acidification:** The ocean is the largest net sink for absorbing CO<sub>2</sub> from the atmosphere and ultimately storing it as carbon compounds and carbonates in the deep. Oceanic absorption of human derived CO<sub>2</sub> has, and will, result in profound changes in water chemistry. The 4<sup>th</sup> IPCC Assessment Report states that the ocean has become more acidic by 0.1 pH units since 1750 and the saturation state of the calcium carbonate minerals calcite and aragonite has been lowered. These minerals are used to form shells and skeletal structures in many marine organisms including corals. These changes in ocean chemistry will reduce the ability of corals to produce calcium carbonate skeletons and increase reef dissolution. There is a natural boundary in the oceans, the 'aragonite saturation horizon', below which corals cannot maintain calcium carbonate structures. As CO<sub>2</sub> levels increase, this aragonite saturation horizon will become shallower and affect numerous stony cold-water coral communities with under-saturated conditions in the next decades, thereby severely limiting their growth and distribution. Projected increases in ocean acidity could result in severe ecological changes for cold-water corals and all organisms associated with the reefs.

**Seafloor Mining:** Mining the deep seafloor for metals is not a viable commercial enterprise – yet, there has been increased interest and investment in mineral exploitation. Potential targets for seabed mining include cobalt-enriched crusts, which occur as thin layers on the flanks of volcanic islands and seamounts at 1000 to 2500 m depth, where cold-water corals also occur. Any mineral exploitation outside areas of national jurisdiction would be governed by guidelines established by the International Seabed Authority (ISA) ([www.isa.org.jm](http://www.isa.org.jm)). Potential environmental impacts associated with the cobalt mining and massive seafloor sulfide deposits were recently reviewed in an ISA workshop.

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*This table details closures to bottom-trawl fishing gear (and in some cases other bottom-contact fishing gear) intended to protect cold-water corals or other potentially-vulnerable deep-water habitats (Adapted from Davies et al. 2007).*

| Country/Area                     | Year designated | Areas Protected to Conserve Cold-water Coral Habitats   |
|----------------------------------|-----------------|---|
| <b>ATLANTIC</b>                  |                 |   |
| Norway                           | 1999            | Sula Reef. Cold-water coral reefs.  |
|                                  | 2000            | Iverryggen. Cold-water coral reefs.   |
|                                  | 2003            | Røst Reef, Tisler Reef, and Fiellknausene cold-water coral reefs.   |
| Azores, Madeira & Canary Islands | 2004            | Deep-water coral reefs (protection made permanent in 2005)  |
| United Kingdom                   | 2004            | Darwin Coral Mounds.  |
| Iceland                          | 2006            | Three closure areas (Reynisdjup Reef, Hornafjarðardjúp, Skaftárdjúp).   |
| Europe                           | 2006            | Capo Santa Maria di Leuca. <i>Lophelia</i> reefs.   |
|                                  | 2007            | Interim closures of the EU sections of Northwest Rockall Bank and Logachev Mounds.  |
| Mediterranean & Black Seas       | 2005            | General Fisheries Commission for the Mediterranean: All Mediterranean and Black Sea areas deeper than 1000 m closed to bottom trawling.   |
| Canada                           | 2002            | Northeast Channel Conservation Area. Deep-water coral.  |
|                                  | 2004            | Stone Fence Fisheries Closure. Cold-water coral reefs.  |
|                                  | 2004            | The Gully Marine Protected Area.  |
| United States                    | 1984            | <i>Oculina</i> Habitat Area of Particular Concern (expanded in 2000).   |
|                                  | 2005            | Oceanographer and Lydonia Canyon Habitat Areas of Particular Concern.   |
| North-east Atlantic              | 2004            | Northeast Atlantic Fishery Commission (NEAFC) prohibited bottom trawling and fishing with static gear on an interim basis in 4 seamount areas (Altair, Antiatair, Faraday and Hekate) and a section of the Reykjanes Ridge in the Mid-Atlantic (closures extended in 2008). |
|                                  | 2007            | NEAFC: 4 areas on Hatton and Rockall Banks closed to protect cold-water corals (boundaries of 2 areas adjusted in 2008).  |
| North-west Atlantic              | 2006            | Northwest Atlantic Fishery Organization (NAFO) closed 4 seamount chains to all demersal gear for 2007–2010 (Corner, New England and Newfoundland Seamounts and Orphan Knoll). In 2007 a Coral Protection Zone was closed to all demersal gear, and Fogo Seamounts in 2008.  |

| Country/Area          | Year designated                              | Areas Protected to Conserve Cold-water Coral Habitats  |
|-----------------------|--|--|
| South-east Atlantic   | 2006   | Southeast Atlantic Fishery Organization: 10 seamount areas (Africana, Discovery/Junoy/Shannon, Malahit Guyot, Molloy, Panzarini, Schmidt-Ott/Erica, Schwabenland/Herdman, Vema and Wust) closed to all fishing activity for 2007–2010.   |
| <b>PACIFIC</b>        |  |  |
| Canada                | 2002<br>2008                                 | Hexactinellid Sponge Reefs in Hecate Strait closed to bottom-trawling (areas expanded and revised in 2006).<br>Bowie Seamount MPA.   |
| United States         | 1983<br>1998<br>2000<br>2006<br>2006<br>2008 | Trawl, bottom-set long-line and bottom-set gillnet use prohibited in US Insular Pacific EEZ.<br>Eastern Gulf of Alaska trawl closure.<br>Sitka Pinnacles.<br>Essential fish habitat closures in Aleutian Islands, Gulf of Alaska Slope Habitat, Primnoa Coral Habitat, and Gulf of Alaska Seamounts.<br>Essential fish habitat closures off California, Oregon and Washington.<br>Essential fish habitat closures in the Bering Sea. |
| Australia             | 1999<br>2007                                 | Tasmanian Seamount Reserve (370 km <sup>2</sup> ) (Commonwealth of Australia, 2002).<br>Southeast Commonwealth Marine Reserve Network.   |
| New Zealand           | 2001<br>2007                                 | Seamounts management strategy, seamount fauna including corals (Brodie and Clark, 2004) 40 000 km <sup>2</sup> .<br>17 Benthic Protected Areas (>1,200,000 km <sup>2</sup> ).  |
| Kiribati              | 2006   | Phoenix Islands Protected Area (expanded in 2008).   |
| North-west Pacific    | 2007   | New RFMO under negotiation. Interim measures adopted in 2007.  |
| South Pacific         | 2007   | South Pacific Regional Fishery Management Organization, new RFMO being developed. Interim measures adopted in 2007.  |
| <b>INDIAN OCEAN</b>   |  |  |
| Eastern Indian Ocean  | 2006   | Southern Indian Ocean Deepwater Fishers' Association voluntary bottom-trawl closures: Agulhas Plateau, Atlantis Bank, Bridle, Coral, Mid-Indian Ridge, South Indian Ridge, Walters Shoal   |
| Western Indian Ocean  | 2006   | Southern Indian Ocean Deepwater Fishers' Association voluntary bottom-trawl closures: East Broken Ridge, Fools Flat, Gulden Draak Seamount, Rusky  |
| <b>SOUTHERN OCEAN</b> |  |  |
|                       | 2007   | Commission for the Conservation of Antarctic Marine Living Resources – Interim measures adopted in 2007.   |

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

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### ABSTRACT

- Coral reefs are generally healthy throughout the Red Sea and Gulf of Aden with 30% to 50% live coral cover at most locations and more than 50% total on average;
- Coral reefs have been damaged near urban and industrial centres from land-filling and dredging; port activities (damage by anchors, oil and wastewater discharges); sewage and other pollution (causing localised coral disease, poor recruitment, and excessive algae); and tourism (damage from anchors and recreational scuba divers);
- Most of the coral reefs in the region severely damaged by coral bleaching in 1998 (approximately 30%) are recovering, especially in the central to northern Red Sea of Saudi Arabia (especially near Rabigh) and in Yemen (Belhaf, Hadhramaut, Socotra Archipelago);
- Outbreaks of crown-of-thorns starfish (COTS) have been reported from the Iles des Sept Freres, Ras Siyyan Marine Protected Area (Djibouti), and on Yemeni Red Sea Reefs;
- Invertebrate populations are generally healthy except for localised declines of giant clams (Egypt) and other molluscs (Sudan), lobsters (all Red Sea and Gulf of Aden reefs) and sea cucumbers (Egypt, Yemen, Sudan);
- Target fish species, especially grouper, are relatively common compared to elsewhere, although there is heavy exploitation in Sudan and Yemen;
- Fishing pressure is increasing at spawning and nursery sites, and sharks are heavily exploited; ornamental fishes are collected in Egypt (recently banned), Saudi Arabia, and Yemen but not yet assessed. The fish community structure adjacent to industry in Aqaba and Yemen has been significantly altered;
- There is some evidence of recent climate change damage on coral reefs;
- Two natural disturbance events affected reefs in 2007: extreme low tides in March caused coral bleaching and mortality on reef flats in Egypt, Sudan, and Jordan; and bleaching killed corals to 20 m depth on 'Rocky Island' in the southern Egyptian Red Sea;

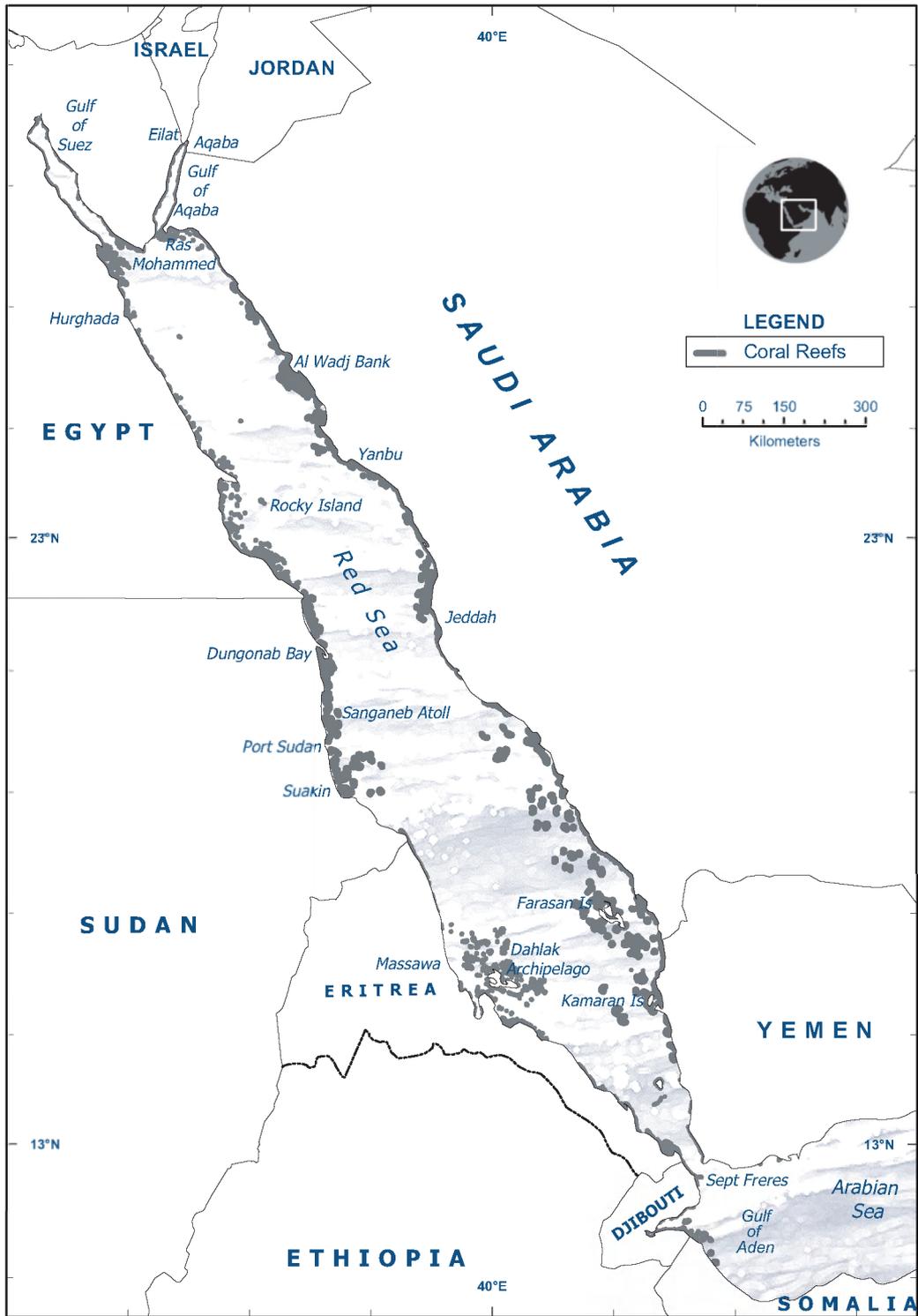
- A volcano on 30 September 2007 damaged some reefs around Jabal Al-Tair island off Yemen;
- PERSGA has issued Regional Action Plans for conservation of coral reefs, marine turtles, mangrove, and seabirds in the Red Sea and Gulf of Aden Region; and
- PERSGA has added climate change impacts to the regional monitoring programmes.

## INTRODUCTION

The Red Sea and Gulf of Aden is a globally significant marine ecosystem, renowned for unique and beautiful marine and coastal environments and high species richness, including many endemic species. The global conservation values of the Region include the diversity of coral reef habitats in the central Red Sea of Saudi Arabia and Sudan; distinct zoogeography and many endemic species; unique coral reefs around the Sinai (Egypt); atoll-like formation of Sanganeb Atoll (Sudan); extensive stands of mangroves and populations of dugong and turtles in the southern Red Sea; unique biodiversity of the Socotra Archipelago (Yemen); and extensive stocks of commercial fishes in the Gulf of Aden.

The living marine resources of the Red Sea and Gulf of Aden have played a major role in the history, development, and cultural heritage of the countries. These waters are a transit route for much of the world's petroleum, dry bulk and other cargoes; thereby providing major challenges to their sustainable use. Traditional uses by the original inhabitants were predominantly ecologically and socially sustainable, however, increasing coastal populations, rapid development and human exploitation threaten the sustainability and special conservation values. In several countries, petroleum industries dominate the economies thereby requiring extensive sea transport and port facilities. International dive tourism growth has damaged some coral reefs at heavily visited reefs, especially in Egypt. Population growth in the coastal zone has led to localised habitat destruction and modification, and pollution, and there is now over-fishing of invertebrates, fishes, and sharks.

Considerable advances have been made in coral reef management and understanding of the marine environment of the Red Sea and Gulf of Aden. PERSGA produced 'The State of the Marine Environment Report', which assesses natural resource status, current issues, needs for additional actions, and constraints to continued progress in environmental management and understanding. There is also significant progress in: the establishment of marine protected areas (MPAs); capacity building and management experience; scientific understanding of some species and ecosystems; improved safety measures for maritime transport; and integrated coastal management. In 2006 PERSGA activated the 'On-ground Projects Programme' which aims to implement a project each year in the member countries on specific needs, for example, in Jordan, 'Education for sustainable development – coastal and marine ecosystem'; in Sudan, 'Capacity building in ICZM'; in Saudi Arabia, 'Mooring buoys for reef conservation'; in Egypt, 'Eco-tourism in managing the mangrove areas'. The regional monitoring programme is to be implemented every two years, with the next survey planned for 2010. Furthermore, PERSGA has integrated the IYOR-2008 in all its planned activities to raise the public awareness about the importance of the marine resources and their conservation, and updating databases including those on biodiversity and MPAs (e.g. MPA global database).



## **STATUS OF CORAL REEFS: 2008**

The following information has been summarised from the 'Country Reports' gathered by PERSGA from its regional experts network (REN), and updated from various sources, including survey and monitoring data from 2004-2008, and the chapters presented on the attached CD.

### ***Egypt***

The diverse coral reefs of the Egyptian Red Sea have evolved from the area's unique geological and bio-geographic features. In the north, the Red Sea rift system splits into the Gulfs of Suez and Aqaba which both have markedly different morphologies. Inside and south of the Gulfs of Suez and Aqaba are extensive fringing reefs which extend from Gubal in the north to Ras Hedarba at the border of Sudan. These fringing reefs are not continuous because periodic flooding from wadies creates gaps, resulting in soft bottom sharms or lagoons. Mohammed Kotb and colleagues recognized 6 basic types of reef and bottom profiles along the Egyptian Red Sea based on the type of bottom, reef width, water depth and topography, influence of floods and gradient of the different reef zones. There are 209 hard coral and 16 soft coral species in the Egyptian Red Sea; while there are about 300 hard coral species in the entire Red Sea. Live coral cover on the Egyptian reefs averages 48% (34% hard coral, 13% soft coral) at the surveyed sites. The Reef Check target fish species estimates are that butterflyfish are the most abundant with 7.2/500 m<sup>3</sup>, with fewer grouper (0.8/500 m<sup>3</sup>) and parrotfish (2.2/500 m<sup>3</sup>).

The coral reefs of Egypt are under increasing pressure from the rapidly expanding tourism industry, which is also an extremely important economic activity. Damage occurs from direct impact of divers and snorkelers, and indirect impacts caused by developing tourism facilities including landfill, dredging for artificial beaches, boat anchors and grounding, and sedimentation. The strategy of assigning carrying capacity to a reef may not be sufficient to limit the impact of divers. Therefore, a more comprehensive framework of approaches is required to limit diver and snorkeller damage. The number of hotels in the Gulf of Aqaba has increased from 5 in 1989 to 141 hotels in 2006: the number of hotel rooms increased from 565 to more than 48 000. Similarly, around Hurghada, the number of hotel rooms increased from a few hundred in 1989 to 35 000 in 2004 and is predicted to reach 75 000 by 2009. Unconstrained development along the Red Sea and Gulfs of Suez and Aqaba will intensify tourism damage to all reefs, especially the fringing reefs.

The number of tourism boats has increased sharply over the last 20 years leading to increased damage from anchoring and boat groundings. In Sharm El Sheik dive boat numbers rose from 23 in 1989 to 350 in 2006 and in Hurghada the increase was from less than 50 to more than 1200 boats. The Red Sea Protectorates Authority reports an average of 15 boat groundings per year. Some anchoring damage has been eliminated since moorings were established from Hurghada to the Fury Shoals. Beaches are prime attractants for resort developers, but there are few natural beaches, so some coastal resorts on rocky shores have created artificial beaches. This not only covers reef habitats, but also the sand is transported down current causing sedimentation and increasing water turbidity.

The Government of Egypt has enacted laws prohibiting discharge of sewage and other contaminants into the Red Sea. Freshwater is scarce in these areas thus most resorts have their own sewage treatment facilities and use the wastewater for irrigation. However, there is

still pollution from: seepage of untreated sewage from septic tanks as the cities lack central sewage treatment; seepage from irrigation waters; and discharge of untreated sewage from day and safari boats.

Two series of COTS outbreaks occurred in the Ras Mohammed National Park in 1994 and 1998. The first outbreak was relatively minor, whereas the 1998 outbreak was extensive and probably continued through 1999 and 2001 although major control programs were implemented.

Until 2 events in 2007 there had been little evidence of climate change impacts on Egyptian coral reefs. Extreme low tides in March exposed reef flats from the Gulf of Aqaba to the Fury shoals, 430 km south of the Sinai Peninsula, resulting in extensive coral bleaching and mortality. The other was a thermal water bleaching event in October, with major coral bleaching to 20 m depth at 'Rocky Island', 450 km south of the Sinai Peninsula. Rocky Island is surrounded by deep water and bleaching followed the September predictions from NOAA of a 'hot spot' in the central Red Sea based on Degree Heating Week (DHW) analyses. The extent of coral mortality was not quantified on this remote area.

**Over-fishing** poses a threat to Egyptian coral reefs through an increase in commercial fishing and heavy trawling in the Gulf of Aqaba, along with poaching in no-take zones. Fisheries in the Red Sea are predominantly seasonal and correspond with the spawning seasons of the most valuable commercial fishes, such that commercial fish populations are under serious threat of depletion.

**Destructive fishing** results from local fishermen, migratory fishermen from other provinces, and visiting fishers from the Nile Delta who use purse-seine nets during the fishing season and then return to their home villages. The traditional local fishers are increasingly abandoning fishing for more lucrative opportunities in the dive industry or in hotels. Newcomers who replace them have less knowledge about the local ecology and often use unsustainable fishing practices, resulting in an increase in habitat destruction from net damage. Also, traditional local fishing knowledge is being irreversibly lost.

**Shark fishing and sea cucumber collection** are more recent threats to Egyptian reefs. The insatiable market for shark fins has induced sharp increases in shark fishing which introduces a conflict with tourism. Sharks in the Egyptian Red Sea constitute a very high commercial resource for tourism: for example, the annual commercial value of an individual shark at the valuable diving site of Brother Island exceeds \$300,000 because these sharks represent the main attraction for divers. The Egyptian government issued a decree banning shark fishing on the Egyptian Red Sea coast in 2004.

After sea cucumbers were depleted in many other parts of the world a small-scale fishery began in Egypt in the late 1990s. By 2000 the sea cucumber fishery had increased greatly because of high prices. In April 2000 the Red Sea Governorate banned sea cucumber fishing in coastal areas under its jurisdiction, however, the sea cucumber fishery was re-opened in 2002 despite the efforts of Egyptian Environment Agency and the Governorate to retain the ban. Between 2002 and 2004 extensive fishing of sea cucumber resulted in serious depletion of the natural stocks and 5 commercial species have disappeared completely from many reefs. All Egyptian authorities agreed to completely ban sea cucumber fishing in 2004. The decline in Egypt's sea cucumber fishery has followed similar patterns elsewhere – a boom followed by a collapse of most stocks.

## ***Djibouti***

There is discontinuous fringing reef growth on the 370 km coastline of Djibouti with the coral reef area being only 12 km<sup>2</sup>, and mostly growing on the fossil reef plateau of the islands of Musha and Maskali. The best reef areas are around the Sept Frères archipelago in the north near the narrow Strait of Bab-al-Mandab and along the Gulf of Tadjoura. Corals grow between 1 m and 45 m depth but the relatively high turbidity limits most coral growth to the upper 15–25 m. A survey in 2007–2008 estimated average coral cover at 56% (33% hard corals and 23% soft corals). Butterflyfish were the most abundant of the Reef Check target species with 6.1/500 m<sup>3</sup>, while grouper were 0.5/500 m<sup>3</sup>, and the parrotfish 1.2/500 m<sup>3</sup>.

Reef Check surveys in 2004 at 19 sites in the Gulf of Tadjourah and Sept Frères region reported coral cover from 5% in the Moucha channel to 65% off Sable Blanc with an overall average of 27.3% in the Gulf of Tadjourah. Earlier surveys in 2002 showed minimum coral cover to be 12%, the maximum more than 60%, and the average 36%. This may indicate that the status of corals is deteriorating. The highest cover reported was 71.9% on north-east Sept Frères, with half of this being soft corals. In the Gulf of Tadjourah the cover was predominantly hard corals, with the highest on the northern coast of Gulf of Tadjourah (66.3% at Sable Blanc and 51.9% at Ras Duan). Whereas there was moderate cover on the southern coast of Gulf of Tadjourah (23.1% at Trois Plage) and Banc d'Ambouli at 42.5%. The lowest cover was on Moucha and Maskali Islands (5% to 35.6%); lower than the minimum cover on Sept Frères of 38.8%.

Djibouti's reefs are under threat from domestic tourism, sewage discharges, shipping and associated spills and pollution, with pressures particularly high around the capital city. Shipping is an important commercial sector as Djibouti 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 so far is limited. There is low level subsistence fishing and limited exploitation of fish for live export but aquarium fish collecting is increasing.

## ***Saudi Arabia***

The Red Sea coast of Saudi Arabia is 1840 km long with extensive coastal fringing, patch/platform, pillar and barrier reefs. The reefs are highly developed in the northern and central Red Sea, but decrease towards the south due to higher sedimentary input. Most reefs in Saudi Arabia are in good condition with the exception of those flanking the major cities of Jeddah, Yanbu and Jizan. The highest coral cover was in the Gulf of Aqaba (51% at 5 m depth, average 46.3%) and on the reefs off Jeddah in the centre with a minimum of 27% (average 30% at 5 m). There were high fish counts in the Gulf of Aqaba (e.g. maximum counts of butterflyfish 8.9/100 m<sup>2</sup>, parrotfish 4.75/100 m<sup>2</sup> and grouper 30.1/100 m<sup>2</sup>), whereas in Jeddah the respective counts were 2/100 m<sup>2</sup>, 2.3/100 m<sup>2</sup> and 0/100 m<sup>2</sup>. Thus fishing is very low in the Gulf of Aqaba but much higher near Jeddah with higher local and tourist populations. Coastal areas along the Jeddah Corniche were in-filled with 700 000 m<sup>3</sup> last year and dredged extensively. The disturbed sediments, petroleum products, industrial pollution and poorly treated sewage are damaging the nearby reefs. Jeddah produces more than 800 000 m<sup>3</sup> of wastewater per day which is discharged into the sea near the centre and south of the city. Fishing and anchoring on coral reefs is a cause for concern. More than 8 accidents occurred in the port during 2006–2007 damaging more than 600 m<sup>2</sup> of coral reefs and spilling 450 tons of oil. Desalination plants pump 2.27 million cubic metres a day of salty, hot water into the sea. All these factors are resulting in extreme environmental stress along the Jeddah coast.

Considerable efforts have been directed to minimize these human impacts on the coral reefs. For example, Saudi government agencies and the private sector have carried out 8 clean up activities on the seabed involving more than 100 divers collecting 2 to 40 tons of waste per month. Land filling along the Jeddah Corniche was suspended by the head of Meteorology and Environment Protection because the contractor was using illegal methods. The Environment Committee of the Mecca Emirate and PERSGA developed an action plan to preserve the Mecca coastal zone in June 2007 with the first step being the installation of mooring buoys at heavily-visited reefs off Jeddah city to eliminate anchor damage.

### ***Sudan***

The 750 km coast of Sudan is characterized by variable biodiversity environments which are attracting many coral reef divers. The status of coral reefs in Sudan is currently good, with no significant changes since the 2004 report. Recent surveys by the High Council of Environment and Natural Resources, Red Sea State in late 2007 reported thick aggregations of COTS damaging the reefs of Talatla Saghir. Risks to the coral reefs are increasing due to the expansion of coastal activities, such as 4 new extensions to the port at Port Sudan using explosives, resulting in very turbid water and sediments which smother corals. Oil exploration is being planned for Suakin and the area of Talatla Saghir and Talatla Kabir.

The most recent surveys estimate an average coral cover of 40% consisting of 25% hard corals and 15% soft corals at the surveyed sites. Butterflyfish were the most abundant of the Reef Check target group with 7.5/500 m<sup>3</sup> while the grouper count was 1.0/500 m<sup>3</sup>, and parrotfish 1.4/500 m<sup>3</sup>.

The immediate coral reef conservation focus in Sudan is coastal and marine monitoring of the Sudanese Red Sea; implementing the existing monitoring programme; training scientists to dive and monitor the Sudanese reefs; and conducting regular monitoring. PERSGA is planning to implement a mooring buoy system at the most popular diving and fishing sites to protect these reefs as tourism development is increasing.

### ***Yemen***

Southern Yemen is in the Gulf of Aden and Arabian Sea Region and reefs extend from the narrow strait of Bab Al Mandab at the southern entrance to the Red Sea to the Omani border in the east. The Gulf of Aden region contains about 70% of the 1400 km long coastline of Yemen and is characterized by rich marine diversity, due to its geographical location, stable meteorology and variable hydrodynamic factors; all of which favour many different marine fauna and flora such as coral reefs, seagrasses and algae. A seasonal upwelling in the Gulf of Aden promotes the growth of macro-algae on most hard substrates, especially to the east and increases primary productivity that supports high biodiversity. This is a major shipping area, thus the international MARPOL convention has designated the Red Sea and the Gulf of Aden as 'special areas'. Oil is exported through Yemen and both exploration and port developments are increasing.

Corals are widespread and generally healthy in this area. The Yemen Liquefied Natural Gas (YLNG) project surveyed several sites in 2005 including the Balhaf area; however, Yemen lacks the capacity to design, implement, and support monitoring and management programs in the area. There are extensive and high-cover coral communities in the Gulf of Aden region,

especially in sheltered and moderately sheltered areas where coral cover is often well over 50% and up to 100% at the best sites, which may spread for hundreds of metres. In Khor Omera, Aden, Shuqra, Balhaf, Bir Ali and Burum the reefs are dominated by branching, foliose, encrusting and massive coral forms, as well as soft corals. The volcanic headlands and small rocky islands near Aden are covered with highly diverse coral communities, including branching, encrusting, foliose and massive formations which often cover 100% of the rocky surfaces. Balhaf and Bir Ali are the most important coral areas in the eastern Gulf of Aden with extensive fringing coral reefs and important fishing areas.

Recent estimates show that average coral cover is 45% (25% hard coral, 20% soft coral) at the survey sites. The target fish populations are dominated by butterflyfish (5.5/500 m<sup>3</sup>), while grouper (0.5/500 m<sup>3</sup>), and parrotfish (0.6/500 m<sup>3</sup>) are less common.

There are several important conservation areas, for example the Five Islands, less than 8 km off Bir Ali, have high coral species diversity (73 hard coral species and 8 genera of other reef cnidarians) at Balhaf. The status of corals in the region is generally good, however, localized damage is being caused around major cities such as Aden and Al Mukalla, including over-exploitation, damage from fishing vessels, artisanal fishermen and small boat use, anchoring, damaging fishing methods, sewage discharges, and shipping and associated spills. Local tourists are over-collecting corals and invertebrates, and trampling over the reefs, especially in the Shuqra area. A major natural stress occurred in September 2007 with a volcanic eruption and earthquakes at Jabal At Tair Island. There were previous eruptions in the 18th and 19th centuries, however the 2007 eruption was strong, with lava shooting 300 m into the air and lava and magma flowing into the sea.

Fish populations have been depleted due to increased fishing effort and the use of non-sustainable gear, such as traps. There is no collection for the aquarium trade. Yemen is developing plans to conserve the marine environment at the national, regional and international levels by applying integrated coastal management under the umbrella of PERSGA. This aims to improve local capacity to plan and monitor coastal development to improve environmental conditions and prevent further degradation (Decree of Prime Minister No.99-2005). This includes protecting the corals and corals communities in the Aden Governorate; but the plan has not been implemented. Some important coastal areas have been proposed as protected areas; Bir Ali is a *de facto* protected area, and could be declared officially in the near future. The area from Balhaf to Burum qualified as an area of regional importance and it is proposed as a Yemeni MPA and included in an ICM Zoning Plan. Yemen recently revised legal and regulatory frameworks, and implemented other measures to conserve the marine environment and their living resources.

## **Somalia**

The 3300 km coastline of Somalia is naturally divided into north and south sectors. The north coast is generally shallow with exposed, high energy sandy beaches and occasional outcrops and cliffs. There are a few coral reefs near Raas Khansir, Raas Cuuda Siyara, and off El Girdi and west of Berbera: these mostly grow on shallow fossilised rocks, 1–10 m deep. The coral communities vary considerably in condition and all have been affected by recent coral bleaching. The shallow reefs east of Berbera have suffered extensive mortality, whereas the deeper reefs (2–5 m) are in better condition. At the Saardin islands 69 species of scleractinian coral, 11 species of alcyonacean coral and 2 fire corals were recorded in 2002, and fish populations

contained many large fish. The last survey 6 years ago showed an average of 50% living coral cover (30% hard coral, 20% soft coral) at the survey sites. Butterflyfish were most abundant with 4.1/500 m<sup>3</sup>, plus grouper (0.6/500 m<sup>3</sup>), and parrotfish (0.9/500 m<sup>3</sup>). The area is both productive and relatively pristine, apart from the effects of coral bleaching and some COTS predation. Somali fishermen target a limited number of demersal stocks and a small range of coral reef fish. Fishing is limited and nearly entirely artisanal, however, foreign commercial fishing occurs on the north coast.

Three areas have been proposed for protection on the north coast but only the Aibat, Saad ad-Din and Saba Wanak area includes coral reefs. There is minimal human disruption to the environment; the only exceptions are relatively heavy, opportunistic exploitation of turtles and sharks. Fisheries and transport are small components of the national economy and pose no significant threats to coral reefs. Somalia is politically unstable thus the ability to effectively implement international or regional agreements is limited and national conservation legislation is virtually non-existent. Increased funding and training of local personnel are required to improve coral reef conservation but this has a lower priority than the rebuilding of the nation and eradicating poverty. The major needs are a system of marine protected areas; the introduction of oil spill response measures; broad-scale environmental education; and monitoring to detect reef deterioration.

### ***Jordan***

The Gulf of Aqaba coastline is only 27 km long, with 30% of this for ports and 30% an MPA. Fringing reefs border 50% of the coast with a high diversity of coral and associated fauna (about 180 coral and 512 fish species). Jordanian coral reefs are in good condition, with up to 90% coral cover in some areas. No major catastrophes have been recorded recently although some localized damage has occurred in areas visited by tourists or close to industrial facilities. There is approximately 45% living coral cover consisting of 30% hard corals and 15% soft corals. The target fish species with the highest abundance are butterflyfish (6.2/500 m<sup>3</sup>), while grouper are 0.9/500 m<sup>3</sup>, and parrotfish 1.2/500 m<sup>3</sup>.

The main threats are oil spills and industrial discharges, municipal and ship-based sewage, and solid waste. Unplanned tourism development may also further threaten the reefs. There is one 7 km long MPA in Jordan (The Marine Peace Park). Jordan has recently revised its legal and regulatory framework for environmental protection at national and international levels, and Jordan is party to 8 regional and international conventions or treaties pertinent to coral reef conservation. There is a need to strengthen institutional capabilities of Jordanian government agencies through hiring and training of staff, implementation of environmental protection laws and regulations, and improving regional cooperation to co-ordinate and enhance the efforts of individual Gulf-bordering nations. Also needed are the development of an integrated coastal management strategy and capacity building at legislative, management and operational levels.

### **SOCIOECONOMIC STATUS**

The socioeconomic significance of artisanal and industrial fisheries is important in the national economies and rural communities in all PERSGA member countries, except for Jordan which has minimal fisheries; however, these have not been studied. There are threats to some fish

stocks, especially vulnerable species such as sharks, cuttlefish, shrimp, and rock lobster. The main reason is a lack of reliable information on fisheries and environmental interactions.

### STATUS OF MANGROVES, SEAGRASSES AND FISHERIES

Mangroves occur as distinct but isolated stands on all coastlines except for Jordan. Those on the Egyptian and Saudi Arabian coasts of the Gulf of Aqaba are the northernmost distribution in the Indian Ocean. Extensive stands occur in the southern Red Sea of Saudi Arabia and Yemen where the continental shelf is wide with stable sediment layers suitable for mangrove growth. There are no mangroves on the Gulf of Aden coast of Yemen apart from a unique, isolated stand in the crater lake at Kharif Sha'ran. There are extensive mangrove areas (*Avicenia marina*) in lagoons separated from the sea by sand dunes around the Socotra Archipelago. Dense, healthy stands of both *A. marina* and *R. mucronata* occur in Somalia. Human uses for mangroves include using wood for fuel, house construction, fence posts, and the collection of leaves for livestock fodder. The latest survey of 79 stands in the region report that 74% are damaged and shrinking rapidly, with the remainder in good condition. The major efforts to conserve the mangrove areas are contained in national and regional action plans, however, the implementation of these plans is proceeding at very variable rates. For instance, all mangrove areas in Egypt are protected and protection is being enforced.

There are 11 species of seagrass in the Red Sea and Gulf of Aden region, ranging from mid-water to 70 m deep. The most commonly recorded species are *Halodule stipulacea*, *H. uninervis*, *Thalassodendron ciliatum*, *Syringidium isctifolium*, and *Halophila ovalis*. Seagrass beds generally occur in protected lagoons and bays with 3 major assemblages along the eastern Red Sea separated by latitude. This suggests distinct biographic groupings. Similarly, three types of seagrass assemblage have been differentiated in the Gulf of Aqaba.

Management of living marine resources (LMR) has not been fully addressed by the countries at both local and regional levels. Sustainable use and management efforts encouraged by PERSG–SAP during 1999–2003 stimulated some actions and initiatives, particularly the management of commercial fisheries resources. However, there are weak statistical data collection systems and countries seek to regulate traditional fishing effort based on inadequate stock assessment studies to reduce effort; inadequate institutional and technical capacity to conduct research and stock assessments; poor legal frameworks for fisheries management and development in many states; no incorporation of internationally accepted modules for management; insufficient monitoring, control, and surveillance systems; poor awareness of the need for and benefits of effective fisheries management by stakeholders in the fisheries sector; and limited fisheries management plans in the member states. PERSGA has built capacity for sustainable management of LMR; developed management strategies for LMR stocks; assessed the environmental effects of fishing techniques; and assessed stocks of fishes and other invertebrates.

### CONSERVATION EFFORTS:

PERSGA has issued Regional Action Plans (RAPs) for conservation of coral reefs, marine turtles, mangroves, and seabirds in the Red Sea and Gulf of Aden Region. These RAPs contain priority actions with these major objectives:

1. Integrated Coastal Zone Management
2. Education and awareness

3. Marine Protected Areas (MPAs)
4. Ecological Sustainable Reef Fisheries
5. Impact of Shipping and Marine Pollution
6. Research, Monitoring and Economic Valuation

Each RAP addressed specific actions, expected results and performance indicators and quality assurance. National Action Plans (NAPs) were developed for each member country in parallel with the RAPs. The implementation of NAPs and RAPs will be variable depending on national capacities, constraints and priorities. Therefore, international agencies and donors are requested to assist in overcoming these constraints. PERSGA has integrated the implementation of RAPs and NAPs into the 2004–2014 strategic plan and established an On-Ground Project Programme (OGPP) to directly support the implementation of NAPs according to resource availability. Furthermore, in 2005 PERSGA member states formulated a regional agreement for biodiversity conservation and establishment of a regional MPA network. In addition, potential climate change impacts on the marine and coastal environment have been included in regional monitoring programmes. Related topics such as sea level rise, coral bleaching, coastal environment degradation will be emphasised in national scientific research plans.

## RECOMMENDATIONS

- Cooperation with international and donor agencies is needed to overcome the constraints of implementing the NAPs and RAPs: urgent assistance is required.

## ACKNOWLEDGEMENTS

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## SUPPORTING DOCUMENTS

The Status of Coral Reefs reports for each of the countries are included in the CD attached to this printed report. In addition, the PERSGA website: [www.persga.org](http://www.persga.org) has the following documents:

Al-Horani FA (2007). The status of coral reefs in Jordan, 7 pp.

Al-Sofyani A (2007). The status of coral reefs in Saudi Arabia Red Sea, 5 pp.

Bawazir G (2007). The status of coral reefs in Gulf of Aden, 5 pp.

Ginawi AGA (2007). The status of coral reefs in Sudan, 5 pp.

Hanafy MH, Kotb MMA (2007). The status of coral reefs in Egypt Red Sea, 40 pp.

Regional Action Plan for the Conservation of Coral Reefs in the Red Sea and Gulf of Aden, 2003. PERSGA technical series, 137 pp.

- Rirache H, Matsumura S (2007). The status of coral reefs in Djibouti, 4 pp.  
Status of the Living Marine Resources in the Red Sea and Gulf of Aden and their Management, 2002. PERSGA, 135 pp.  
The Status of the marine environment report for the Red Sea and Gulf of Aden, 2006. PERSGA technical series, 241 pp.

#### THE CORAL REEFS OF ERITREA: LITTLE KNOWN GEMS

Eritrea has had a troubled recent history, such that little information has come out on the status of their coral reefs. However, there have been recent exciting findings from a major initiative, the Eritrea Coastal Marine Island Biodiversity Project (ECMIB, funded by GEF, administered by UNDP and implemented by the Ministry of Fisheries). Since 2004 this has focused on building capacity, assessing the coastal resources and building the platform for conservation. The project found that Eritrean reef resources are indeed rich in the 3 distinct zones where coral reefs grow along the 1350 km long Eritrean coastline and more than 350 offshore islands in the central Red Sea. Each region contains globally important and unique assemblages of species with some of the most spectacular coral reefs in the world. Most of the coastline is sparsely populated, with Massawa and Assab the two main population centers, and only 7 of the offshore islands are inhabited: hence there are few human stresses, except for some land reclamation, sedimentation, and resort developments at Massawa and nearby islands. There has also been some anchor and diver damage but fishing and curio collection is minimal. The ECMIB project trained 53 Eritrean nationals overseas to assess biodiversity, especially on coral reefs, mangroves and seagrasses, as well as marine turtles, dugong, algae, birds and perform socioeconomic surveys. Another 40 nationals were trained locally with a focus on field work. They have surveyed 96 coral reef stations (68 using Reef Check protocols; 16 using video and photo transects, photo quadrats using AIMS methods adapted for the Red Sea; and 12 for coral taxonomy). Prior to 2007 only 154 coral species were known from Eritrea; however, visits to the northern Dahlak islands, the southern Dahlak islands and Assab islands found that coral cover can reach 100% in deeper waters, and the number of coral species has jumped to 220 in 38 genera. Included were 5 new species and perhaps a new genus. There was limited bleaching damage: the possibly exists that Eritrean corals may be resistant to wide temperature variations because local water temperature can reach 37.5°C in summer at 10 m depth. These warm waters of Eritrea now contain flourishing coral reefs that cope easily with warmer water; this may provide the reservoir to re-seed reefs damaged by climate change bleaching with corals that can grow at higher temperatures. It also may mean that Eritrea can develop a lucrative tourist industry based on divers who want to enjoy some of the world's few remaining flourishing coral reefs. In addition, there is spectacular beauty on land and famous archaeological sites. Thus the government now has the responsibility of advancing conservation to protect these resources. Already they are planning to develop Sheikh Seid and Dissei-Madote islands as Eritrea's two first MPAs and a new GEF project may expand this to larger areas around the Buri peninsula (from Virginie Tilot, 'Charlie' Veron and Alain Jeudy de Grissac).

## 5. STATUS OF CORAL REEFS IN THE ROPME SEA AREA (THE PERSIAN GULF, GULF OF OMAN AND ARABIAN SEA)

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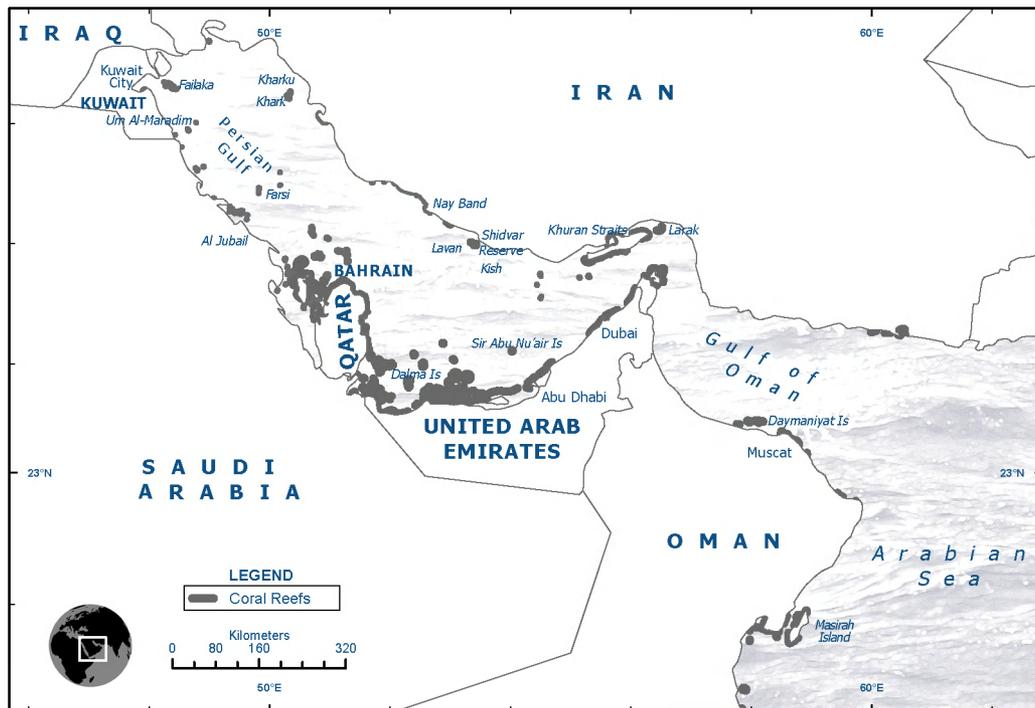
### ABSTRACT

- These coral reefs grow under extreme conditions of highly variable salinities and temperatures, thus representing excellent models to study global climate change. However, in 1996, 1998 and 2002, there were massive losses from coral bleaching;
- New surveys around 16 Iranian islands have provided new information on hard and soft coral communities: Khark, Kharku, Farsi and Larak islands have the highest coral cover, Kish Island has the highest species diversity;
- There was significant coral bleaching in Iranian waters in August 2007 with few eventual affects in the southern Persian Gulf;
- Bahrain is in severe danger of losing all its coral reef resources through a combination of severe natural stress and inappropriate marine engineering works;
- Coral communities in Oman (Gulf of Oman) were severely damaged by Cyclone Gonu in June 2007. Corals on exposed shores were almost entirely eliminated; damage in sheltered bays, coves and islands was variable; there are signs of recovery;
- Halul Island (Qatar) and Ras Ghanada (Abu Dhabi) are identified as coral biodiversity hot spots; Yasat and Dalma Islands (Abu Dhabi) have significant coral cover. Management plans have been developed for these areas by the governments in Qatar and Abu Dhabi;
- Most coral communities off Qatar are essentially extinct due to stress from extensive coastal engineering, although some offshore reefs have good coral cover;
- Research and monitoring of artificial reef effectiveness is a high priority in Qatar;
- Capacity and interest in managing and monitoring coral resources in the region has increased in the past 5 years, largely due to coordination by Iran, but strengthening coral resource management capacity is urgently needed. Large areas have not been surveyed.

## INTRODUCTION

Coral diversity in the Persian Gulf and parts of the Gulf of Oman (collectively called the ROPME Sea Area, or RSA) is relatively low compared to most parts of the Indian Ocean where it is up to four times higher. This is largely due to extremes of water temperature and salinity that are close to the physiological tolerance limits of many species, the normal stress and environmental gradients experienced by coral communities at high-latitudes, and because the Persian Gulf is still geologically a very young body of water. The coral fauna of the RSA is a combination of widespread Indo-Pacific species and a few regional endemics, the latter mostly found in the Gulf of Oman. Hard coral species richness on the Gulf of Oman communities (about 120 species) is almost double that of the Persian Gulf (about 68 species). Compared to the Indian Ocean, the proportion of the Acroporidae and Fungiidae species is significantly under-represented in the inner Gulf, while the Siderasteridae and Faviidae are disproportionately higher in the Persian Gulf and the Gulf of Oman. Only one endemic coral is found throughout the RSA, *Acropora arabensis*.

A thin coral reef framework fringes the Saudi Arabian, Bahraini and Iranian coastlines in the central sectors of the Gulf. Further south in the territorial waters of Qatar and UAE, as well as in Kuwaiti waters to the north, there are fringing reefs around offshore islands and patches have formed in waters deeper than 10 m. Coral spawning has been observed in the Gulf and recovery of a coral community in Dubai following a series of mass bleaching events was due to successful recruitment of larvae that probably originated from colonies growing in deeper water.



The annual temperature range in the Persian Gulf is the most extreme known for any coral region: extreme low temperature events can reduce temperatures to 4°C in shallow water, and to 14°C offshore. Long-term temperature data from the Saudi Gulf coast show that extreme temperature events of less than 6°C, have occurred 3 times since 1945 and probably caused widespread coral mortality, particularly when these coincided with low tides. Extreme high temperatures also result in mass bleaching and mortality in shallow water. Both the extreme maximum and minimum temperatures are key determinants of reef growth and structure in the Persian Gulf. Extreme salinity (up to 50 ppt – normal is about 36 ppt) often occurs in the semi-enclosed embayments and shoals of UAE, Qatar and Bahrain which further exacerbates the harsh conditions. Light is also a significant constraint in water more than a few metres deep because of the high turbidity associated with ‘shamal’ (high wind) events in shallow muddy areas and low sun angles in winter.

The GCRMN regional Node for the RSA was formed to motivate coral reef conservation and management. The Iranian National Center for Oceanography (INCO) was selected to host the GCRMN-RSA Node in December 2003 at a workshop on Kish Island, Iran, where regional experts developed a short-term coral reef program to identify capacity gaps and training needs, as well list the key stakeholders. The meeting called for the participation and collaboration of national institutions and ministries such as Environment, Fisheries, Tourism, Universities and other relevant scientific and research organizations to initiate activities. Technical and financial support for this has been requested from regional and international entities such as ROPME, IOC/UNESCO, IUCN, GEF, UNEP and WCMC. The main objective was to build the capacity of coral reef experts in the region; therefore INCO organized the following workshops and planning meetings:

- Planning Meeting for an Ocean Data and Information Network for the Central Indian Ocean (ODINCINDIO), October 2004;
- Regional Meeting on Trans-boundary Diagnostic Analysis of the Coastal and Marine Environment of the RSA in May 2005;
- Regional meeting on Priority Program Activities and Networking for the Conservation of Coral Reefs in the RSA, July 2005 in collaboration with IOI-IRI office, ROPME and GCRMN; and
- Regional Workshop on Monitoring Methods, Data and Information Management of Coral Reefs Tehran, Iran, February 2007.

National status reports from each of the littoral countries were presented between July 2005 and February 2007 at each of these meetings; these are summarized in this report and available on the accompanying CD.

## NATIONAL STATUS OF CORAL REEF REPORTS

**Bahrain:** The coral reefs are mainly distributed along the northern and north eastern shores. There are about 31 coral species, including 25 hard coral species in 19 genera. Bahrain risks losing all its coral reefs unless action is taken immediately. The losses are apparently due to inappropriate engineering which has resulted in a ‘bed of rubble’ that is all that remains of Fasht Al Adhm (the reef complex between Bahrain and Qatar), and excessive sedimentation. An additional threat will come from the proposed causeway linking Bahrain with NW Qatar. The Directorate General of Marine Resources has an on-going coral reef project that uses divers to survey and photograph most of the coral reef habitat. Bahrain has requested support

from ROPME to provide experts to identify coral reef species and scientifically evaluate the status of Bahrain's coral reefs. Another on-going project (Bahrain Habitat Survey Margis II), in cooperation with Bahrain Center for Studies and Research, uses satellite images but is presently incomplete due to a lack of funds. It is expected that results will eventually highlight the status of the marine habitat. It will be facilitated if financial support can be arranged through ROPME to bring in experts and facilitate monitoring.

**Sultanate of Oman:** There are 4 principal areas of coral growth along the Omani coast: Musandam Peninsula; Daymaniyat Islands, Capital Area and Sharquiya coast to Ras al Hadd; South-west coast of Masirah Island and Barr Al Hikman; and Dhofar area, especially the Al Hallaniyat Islands and Mirbat Peninsula. About 107 species of hard corals have been recorded in Oman but it is estimated that an additional 20 species will probably be found with more taxonomic effort.

The reefs around the Musandam Peninsula were described as virtually 'pristine' in early 2007 with no evidence of natural or human damage; some had coral cover in excess of 80% in 50–100 m long transects in 2–4 m depth. The dominant corals were species of *Pocillopora* and *Acropora*. It is unknown how these specific reefs fared during Cyclone Gonu. Coral communities in northern Oman were extensively damaged by Cyclone Gonu in June 2007 (Box p. 83), although the only surveys have been around the Muscat Capital Area from Bandar Khiran, west to Ras Sawadi and the Daymaniyat Islands. A comparison of data collected prior to the cyclone, immediately following, and one year later, indicate variable recovery depending on location, depth, exposure and impacts associated with freshwater runoff.

Prior to the cyclone, steep exposed northern shores of island and mainland sites had dense soft coral communities (10–70% total cover) interspersed with occasional massive *Porites* and/or *Goniopora* colonies, occasional *Acropora* colonies and small encrusting or massive growth forms of other genera (e.g. *Platygyra*, *Favites*, *Symphyllia*). Shallower horizontal seafloor areas above 12 m depth supported more diverse and extensive hard coral assemblages dominated by *Acropora*, *Stylophora*, and *Pocillopora damicornis*.

Severe impacts have been observed at exposed reefs throughout the wider Capital Area at depths less than 8 m, where coral cover was reduced by up to 90% immediately following the cyclone. Even large resilient massive colonies of *Porites lobata* and *P. lutea* were heavily scoured by sediment and rubble or moved large distances by the waves. Many exposed areas suffered lower mortality (around 30–80%) reductions in soft and hard coral cover. Repeat surveys one year later show some recovery including recent recruitment of hard corals and good re-growth of soft corals at island and mainland locations, although little change has been seen at the most heavily damaged shallow water sites at the Daymaniyat Islands and on the mainland coast.

Less exposed areas at the Daymaniyat Islands and Ras Sawadi have mixed coral assemblages dominated by either *Acropora*, or *Pocillopora* or *Porites* depending on location and depth. Dense branching and table *Acropora* assemblages were heavily damaged with major losses of reef structure and significant colony mortality (25–70%) in most areas. A year later there are indications of recovery with *Acropora* re-growth from fragments and new recruits at many shallow water sites around the Daymaniyat Islands; recovery is less obvious in deeper, more marginal coral areas of the islands and some mainland sites where there were fewer *Acropora* corals.

### CYCLONE GONU CAUSED SIGNIFICANT DAMAGE TO CORAL REEFS

There are usually fewer cyclones in the Arabian Sea than other tropical regions, including the Southern Indian Ocean and the Bay of Bengal. Usually only 2–3 tropical cyclones per year occur in the region out of a global average of 100–150 per year and only a small fraction have hit the Gulf of Oman since reliable records began in 1876: only 2 cyclones have hit the Gulf of Oman in the last century.

On 1 June 2007, Cyclone Gonu formed in the eastern Arabian Sea north of the Lakshadweep Islands and tracked northward, building to a category 5 storm by 3 June – the strongest cyclone on record in the Arabian Sea. By June 5, Cyclone Gonu had dissipated to a category 2 storm and made landfall at Ras Al Hadd. It continued to follow the Omani coast of the Gulf of Oman towards Muscat where it veered north-west and struck the Iranian coast as a severe tropical depression. The human and economic costs of Cyclone Gonu were considerable with about 75 deaths and US\$4.25 billion in damage.



Extensive mono-specific stands of *Pocillopora damicornis* are a distinctive feature of a number of sheltered or protected island and mainland sites in the Gulf of Oman. In these areas, cyclone impacts were variable, with the largest changes in coral cover found in exposed areas above 6 m depth; the greatest coral losses were at Cat Island, Fahal Island, Ras Sawadi and the Daymaniyat Islands with the first two areas showing 75–90% mortality. Sheltered sites had more variable mortality dependent on patch size, depth and exposure. Approximately half the stands at Ras Sawadi and the Daymaniyat Islands are largely intact with indications of new recruitment and re-seeding of some rubble areas. Massive *Porites* colonies in more sheltered areas were largely unaffected by waves, however, freshwater runoff in areas with low flushing rates (e.g. Khawr Yenkit and Bandar Khayran) caused significant shallow water mortality. No coral bleaching or crown-of-thorns starfish (COTS) outbreaks have been reported recently, although limited evidence of heat induced fluorescing was seen amongst shallow water Poritids at the Daymaniyat Islands (August 2008).

**United Arab Emirates (UAE):** The offshore islands and banks of Abu Dhabi support some of the most important coral resources in the Persian Gulf. In a few limited areas, coral communities have formed a rudimentary reef framework several metres thick, while the majority of corals occur in either high cover coral carpets or in sparse communities of widely spaced colonies. From January 2005 to December 2007 a coral reef study in the south-eastern Gulf off Abu Dhabi and Eastern Qatar assessed the condition and potential recovery of degraded coral communities following bleaching in the summers of 1996, 1998 and 2002. This was perhaps the most comprehensive study in these waters and is summarised below.

|             |                                      |  |
|-------------|--------------------------------------|--|
| Summer 1996 | 2.5°C above average for 3 months     | Widespread <i>Acropora</i> mortality               |
| Summer 1998 | 2.5°C above average for 4 months     | Mortality (100% in some areas) among other species |
| Summer 2002 | 1–1.5°C above average for 1 month    | Further bleaching of surviving corals              |
| 2002 – 2005 | No significant temperature anomalies | Recovery period                                    |

One coral biodiversity hot spot stood out: Ras Ghanada (Abu Dhabi), while Yasat and Dalma Islands also had good growth and high cover – elsewhere coral cover remains very low following 10 years of natural and human stresses. Coral diversity is low but no regional coral extinctions were reported: 43 hard coral species are now known, an increase from 36 species previously recorded from Dubai. Many sites show strong coral recruitment indicating healthy coral communities upstream that supply the larvae. Seawater temperatures were remarkably uniform in the area over 24 months, varying from 16.2 °C to 36.2 °C. It is hypothesised that frequent mass mortalities due to thermal stress return coral communities to early stages of succession and probably explains why there are no flourishing reefs.

There was significant wave damage to corals on the UAE Gulf of Oman coast at Jebel Khor Fakkan during Cyclone Gonu. The major octocoral communities are dominated by *Sarcophyton*, *Sinularia*, *Dendronephthya*, gorgonians and seawhips with occasional hard corals on rocky areas, constituting 3–10% total cover (main genera include *Acropora*, *Porites*, *Goniopora*, *Platygyra*, *Favia* and *Favites*). The cyclone affected colonies down to 7m depth with major impacts to *Sinularia*, *Sarcophyton* and *Acropora*. By March 2008 there was significant re-growth of some soft coral areas after the cyclone, although hard coral communities in shallow exposed areas have shown less resilience. COTS (*Acanthaster planci*) were killing many of the few surviving *Acropora* colonies in March 2008.

Extensive reefs occur in the extreme west of Abu Dhabi near Ruwais with generally less than 10% coral cover and 20 species which are reportedly in good health with no signs of damage. Similarly there is extensive and rich coral growth at Ras Ghanada (coastal) and Yasat and Dalma islands; all showing good coral growth and high coral cover (60–100%) with 36 species of hard coral. Sir Abu Nu'air Island is 100 km offshore from Abu Dhabi and has cover as high as 50% in small areas. The island is a Sharjah protected area with a turtle nesting site: there are plans to develop a luxury eco-resort which may increase resource conservation.

More expansive hard coral communities occur at Mirbah where an extensive inshore reef is dominated by branching and table *Acropora* along with *Platygyra*, *Porites*, *Favia* and *Favites*. Coral cover of 50–90% was common prior to the cyclone in areas up to 50 m<sup>2</sup>. The only damage was limited local anchoring of fishing vessels and the use of wire fish traps, which have locally reduced populations of parrotfish, butterflyfish and angelfish. Waves from the cyclone caused a significant decline in coral cover of branching *Acropora*, *Stylophora* and *Pocillopora*, reducing total coral cover by 50–85%. More resistant corals, including *Platygyra* and *Porites*, were less affected. Extensive algal colonisation of coral rubble followed shortly after the event. Subsequent signs of recovery were evident in March 2008 due to re-growth of fragments. COTS were also recorded in higher numbers after the Cyclone and were visibly impacting *Acropora* colonies.

A coral reef management and monitoring plan has been developed to address the most important human threats, and a network of 8 monitoring stations installed in Abu Dhabi by biologists from the Environment Agency Abu Dhabi trained in data collection, analysis and reporting.

**Qatar:** Fringing reefs occur along the north and east coasts, with generally high coral cover but low species diversity (<20 species). The south-eastern Persian Gulf WWF/NCRI study also extended into eastern Qatari waters. The study identified Halul Island as one of the two key coral biodiversity hot spots in the area. Monitoring has been established at 25 sites in 10 locations where the coral species richness varies from 0 to 20 species. The management plan for the south-eastern Gulf includes eastern Qatari waters. Other coral management initiatives include a detailed study of artificial reef module performance being funded by the larger energy companies operating in Ras Laffan.

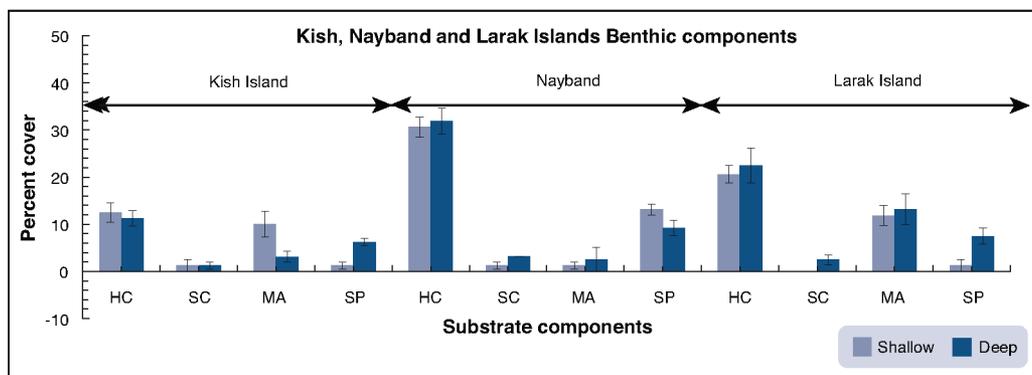
**Kuwait:** In Kuwait 35 coral species have been recorded, including 29 reef-building corals, and 6 non-reef-building species. The main coral reefs are patch and platform reefs around the islands of Kubbar, Qaro and Um Al-Maradem. Kubbar Island has least species diversity and the predominantly *Porites* reef extends 1.3 km around the island and up to 900 m from the shore. The most diverse coral reefs occur around the small island of Qaro (about 200 m long) with the reef extending 1.3 km around the island and up to 600 m from the shore. *Acropora* dominates the coral community. Um Al-Maradim Island is 550 m long with a 1.4 km long reef extending 1.1 km from the shore. The dominant species are *Porites*, *Acropora* and *Stylophora*. There are also small patch reefs. Artificial reefs constructed with concrete blocks of different shapes and sizes have been deployed since 1995 on Jaber Al-Kuwait Reefs by the Kuwait Dive Team to compensate for the slow deterioration of natural reefs.

**Islamic Republic Of Iran:** There are coral reefs around 16 islands from the north-west to the south-east and some limited areas around Nay Band Bay. The highest coral cover occurs around Khark and Kharku islands in the far north, Farsi Island in the middle north, and Larak Island on the Iranian side of the Gulf. About 36 species of hard corals have been documented so far by INCO, with Kish Island showing the highest species diversity. Coral cover in 2006 around Farurgan Island was mostly concentrated in the west and north-west of the island with mean coral cover of 25.9% ( $\pm 5.8$ ), whereas around Hengam Island it was mostly concentrated on the eastern side of the Island (48.6%  $\pm 1.4$ ). There was a significant difference ( $p < 0.01$ ) in hard coral coverage among different reefs in each island. Other benthic life forms showed similar patterns with significant differences ( $p < 0.01$ ) among reefs. The predominant hard coral forms were massive (*Porites*) in Farurgan Island whilst those in Hengam Island were mainly

branching corals (*Acropora*). Non-scleractinian corals included Alcyonaceans, 8 of which are new records for Hengam and one for Farurgan islands. Soft corals showed higher diversity and density in the south and north-eastern parts of Hengam Island, but were sparse and isolated in Farurgan Island. There are low density, patchy populations of octocorals, which have been poorly studied because they occur at greater depths. Studies have identified more than 30 species in 21 genera; much less than the 90 genera of Alcyonacea elsewhere in the tropical Indo-Pacific. Octocorals occur along the Iranian side of the Persian Gulf from the Strait of Hormuz to Khark and Kharku Islands in the western part. Populations and density of octocorals varies considerably between the northern Gulf compared to southern parts. The genera in shallow water to around 10 m depth have symbiotic algae (*Simularia* and *Sarcophyton*) whereas those below 15 m depth do not have photosynthetic symbionts.

Iranian scientists monitored Kish Island reef before and after the bleaching of mid-August 2007 which affected reefs on the eastern side and probably other parts. Approximately 20% of bleached corals were branching *Acropora*, especially where the seabed has a shallow slope which made branching corals vulnerable to high water temperatures during low tides. Other corals such as *Favia*, *Platygyra* and *Porites* appear to be more resistant to temperature stress. More follow-up survey and monitoring of Kish Island, and sister islands Hendourabi and Farur, is needed to estimate the extent and severity of bleaching on the coral community. Public awareness, management and conservation of corals have increased considerably on Kish Island and drastic measures are required to reduce the human stresses on coral reef and associate communities.

Recent temperature stresses, both hot and cold, have been among the most important causes of the vast destruction of the inner Gulf reefs (and other reefs around the world). Tissue chlorophyll content and ultraviolet radiation index were monitored in 3 major genera of hard corals on Kish Island over one year. Results show that *Favia* sp. is more sensitive to cold stress and that this stress results in chlorophyll enhancement in reef tissue in the studied area. Two other genera (*Acropora* and *Porites*) did not show the same sensitivity to cold stress, which is consistent with previous findings of a trend in coral reef communities towards decreasing massive corals and increasing branching forms.



**There is 15% to 35% coral cover (hard and soft) on the coral reefs in Kish Island, Nayband Bay and Larak Island in shallow water (3 m) and deeper water (9 m). HC – hard coral; SC – soft coral; SP – sponges; MA – macroalgae (from Maghsoudlou 2005)**

## THREATS TO CORAL REEFS OF THE REGION

Human pressures constitute the major threats to coral reefs in the region, especially from coastal development, the oil industry, unsustainable fishing and poor treatment of liquid and solid wastes.

| <i>Country</i>      | <i>Threats</i>   |
|---------------------|--|
| <b>Kuwait</b>       | Fishing and recreational boating, solid litter that smothers reef organisms, oil pollution, discharge of ballast water, coastal development, global warming.   |
| <b>Oman</b>         | Coastal development, destructive fishing, hazardous/solid waste, over-fishing, depletion of rare species, oil pollution, trampling, eutrophication and siltation due to coastal development.   |
| <b>Saudi Arabia</b> | Discharge of sewage from vessels, ship discharge of solid waste, oil spills from exploration, production and transport, illegal disposal of toxic wastes, global warming effect, diseases.   |
| <b>I.R. Iran</b>    | Oil production and pollution, temperature fluctuations, breakwater construction, sedimentation during land reclamation, dredging, depletion of corals by local people, fishing for aquarium trade, extensive anchor damage, discharge of nutrients and sewage. |
| <b>U.A.E</b>        | Coastal development, oils spill, sewage, anchoring, over-fishing, COTS, increasing coral disease by human stressors. Dredging to build a large port off Ras Ghanada will stress local reefs.   |
| <b>Bahrain</b>      | Coastal development, anchor damage, over-fishing, spear fishing, solid wastes, oil pollution, trawling nets, sedimentation.  |
| <b>Qatar</b>        | Coastal development, bleaching, local fishing boat anchors, oil pollution.   |
| <b>Iraq</b>         | There are no coral reefs in Iraq.  |

*These major threats to coral reefs of the Persian Gulf and Gulf of Oman were determined by regional experts during meetings from 2003 to 2007.*

## GAPS AND EXISTING CAPACITY OF THE REGION

**Littoral Country Capacity:** During meetings from 2003 to 2007 regional experts agreed that there were some local capabilities for coral conservation and research in the region including:

- Local diving facilities in each country and consultants e.g. the WWF, Dolphin Energy initiative;
- Private professional divers, especially those working in the oil industry;
- Universities and marine colleges along the coast;
- UN University is working with local experts in assessing the marine environment in the Emirates; and
- National data centres in some ROPME countries within the framework of ODINCINDIO.

**GCRMN-RSA Node (INCO) Capacity:** The Responsible National Oceanographic Data Center in the Persian Gulf (RNODC-PG) was established in April 2004 at INCO and there is enough capability in this section to establish a Regional Coral Reef Data Center for the RSA, provided

a small budget is available for equipment and training of coral reef database operators (for data entry, verification, analysis and preparing regional summaries). In addition to RNODC responsibility, INCO has participated in the ODINCINDIO Project since October 2004.

#### SEVERE BLEACHING IN THE NORTHERN GULF, 2007

Corals in the Persian Gulf have suffered from extreme levels of bleaching and mortality due to sea surface temperature (SST) anomalies: these drastic stresses have probably been more severe than anywhere else in the world with the potential for long-term consequences. There have been 5 major recent temperature anomalies in the Gulf (1964, 1981, 1996, 1998, and 2002), but much remains to be learned about how coral reefs respond to such thermal challenges. Even if bleaching events are part of a natural pattern of reef development and occur periodically, there is insufficient knowledge about the long-term consequences of repetitive bleaching events.

Between 10 and 28 August 2007, coral bleaching occurred in the northern Gulf, while there were no reports from the southern Gulf. The extent of bleaching along the Iranian coastline is unknown, but it affected the islands of Kish, Farur, and Hendorabi, when mean SSTs reached 36.2°C, and 34.2°C at 10 m depth and remained like this for about one month. This constant heat stress triggered bleaching such that fewer than 5% of the coral colonies appeared normal after 2 weeks; most corals were partially or fully bleached. Most *Acropora* species bleached within the first days while more resistant corals like *Favia fавus*, *Platygyra daedalea*, and *Porites* spp. survived. Two weeks later, all *Acropora* species had bleached and the more persistent genera were pale or bleached. After 6 months the extent of mortality was evident in Kish Island and Hendorabi Island: no live or juvenile *Acropora* colonies were found around Kish Island and only two juvenile colonies were found on Hendorabi Island. Dead coral skeletons were covered with filamentous algae, however, in deeper parts (around 6–8 m) new coral communities of *Porites* spp., *Favia fавus*, *Platygyra daedalea*, *Pavona decussatea*, *Siderastrea savignyana*, and *Psammocora* sp. appeared to have survived. The *Porites* species were dominant among the communities and most of the *P. lutea* recovered after bleaching.

**Regional needs for coral reef conservation and management:** Regional experts identified a number of significant needs and actions to improve coral reef conservation, including:

- Immediately reduce diver and boat anchor damage. Mooring buoys should be installed at major reef sites in all countries to prevent further anchor damage to corals. Additionally, spear fishing should be banned (and the ban enforced) to allow reef fish populations to recover;
- Solid waste cleanup projects are needed in each country to remove accumulated debris from the reefs, including plastics, metals, glass, and discarded fishing equipment;
- Public education campaigns are needed to increase understanding of the importance of coral reefs and their sensitivity to damage and pollution. These should highlight the use of moorings to prevent damage to corals, the need for fishing restrictions on reefs, the problems caused by littering and refuse, and the need for public and private participation in the management of coral reefs;

- Develop and expand local capacity to monitor and carry out coral reef research. This must also include the designation, where applicable, of competent authorities to manage and conserve coral reefs, and preparation of detailed management plans to promote sustainable and wise use of reef resources;
- Designate additional Marine National Parks and Marine Protected Areas (MPAs) as part of integrated management plans. These are the only mechanisms that will allow countries to fully protect their coral reefs;
- Coastal development, and in particular dredging and land filling, should either be curtailed or properly managed. The use of silt curtains should be mandatory in landfill operations and only after stringent Environmental Impact Assessments. Coral reef areas should never be approved for land filling, acknowledging their scarcity throughout the region;
- Improve navigational aids and radio communication in these waters, especially on major shipping channels; and
- Implement current Oil Spill Contingency Plans, including the development of site specific plans, and improve capacity to respond to spills of oil and other hazardous materials, including a review and upgrading of port reception facilities for solid and liquid waste.

#### **RECOMMENDATIONS FOR DEVELOPMENT OF GCRMN ACTIVITIES**

ROPME countries in the region consider that the following actions are necessary to improve the capacity to monitor, research and conserve their coral reefs:

- Transfer training and monitoring to communities by establishing training teams in each country (through appropriate training courses);
- Design and implement Strategic Capacity Building Programs according to the needs of each country and the region;
- Improve recognition of the national monitoring networks in each ROPME country and facilitate collaboration and interaction among the core institutions and the agencies of the GCRMN Node to consolidate the network, and for the exchange of data amongst neighbouring countries;
- Establish and equip a regional database centre, as well as establishing a national database centre in each country that interacts closely with the regional/sub-regional Node database;
- Improve public awareness through annual reporting, updating of the web site, regular working and information workshops, poster and media materials (a preliminary website was developed by INCO at [www.inco.ac.ir/coralreefs/home.htm](http://www.inco.ac.ir/coralreefs/home.htm)); and
- Design and implement Coral Reef Action Plans according to the needs of each country and region, and develop robust integrated coastal management facilities to mitigate impacts from activities on adjacent areas as well as transboundary stresses e.g. shipping, oil exploration.

#### **CONCLUSION**

About 5 years after establishing the GCRMN Node in the Persian Gulf and Gulf of Oman and conducting many essential actions in the region, there is a need to transfer field training and monitoring to at least three national GCRMN sites in the region. This will serve to assess equipment and on-going training needs for each country throughout the Node, so that capacity

building strategies can be improved. Assistance from the GCRMN Global Coordination is requested to assist the region and countries, identify existing national and regional monitoring capabilities and activities, advise on current monitoring and logistic capacity and needs for network development. Regional experts consider that the application of successful strategies, such as those in South East Asia and also the ICRI Middle East Strategy developed in Aqaba in 1997, will prove effective in rapidly developing cost-effective plans for conservation and management of coral reefs in the region.

### **AUTHOR CONTACTS**

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## 6. STATUS OF CORAL REEFS IN EAST AFRICA: KENYA, TANZANIA, MOZAMBIQUE AND SOUTH AFRICA

NYAWIRA MUTHIGA, ALICE COSTA, HELENA MOTTA, CHRISTOPHER MUHANDO,  
ROSE MWAIPOPO AND MICHAEL SCHLEYER

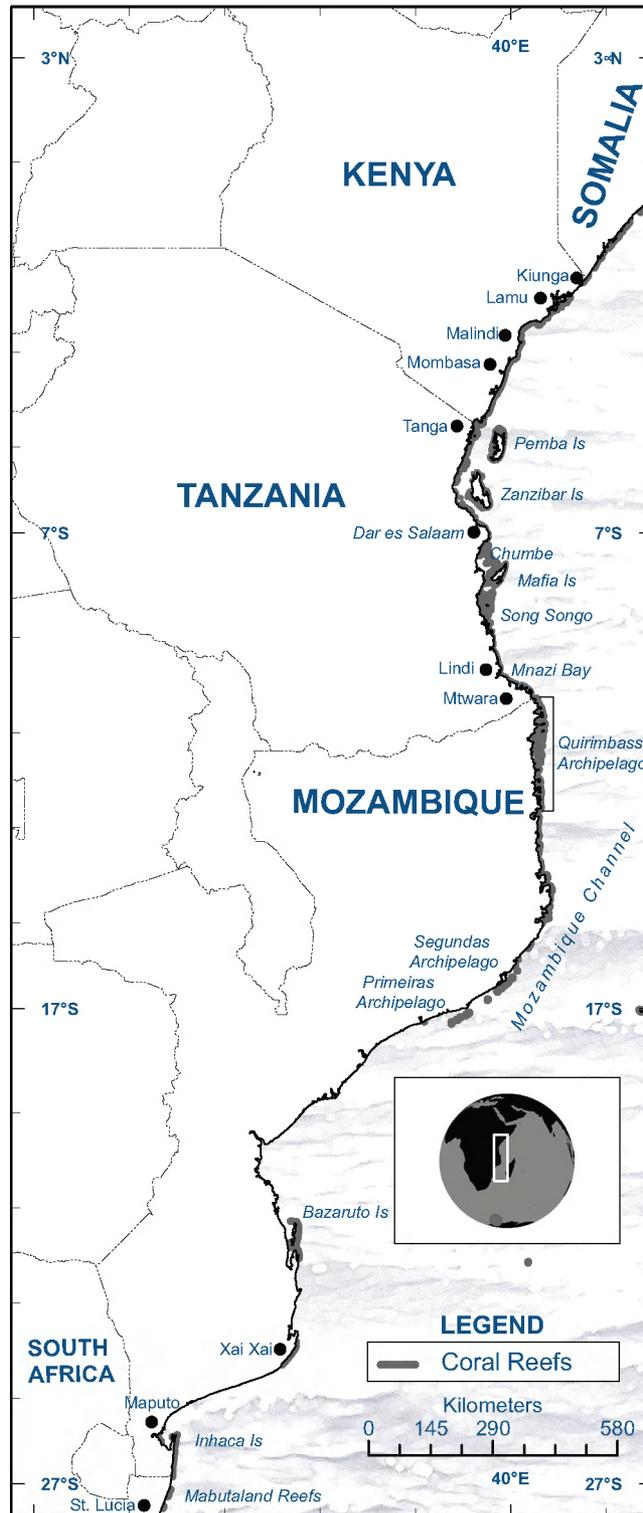
### ABSTRACT

- Many reefs have shown good recovery after the massive losses in 1998 but recovery was slowed on other reefs by fishing and other ecological factors, including COTS infestations;
- The management of coral reefs is improving with more MPAs and increased management effectiveness; and the number of non-traditional forms of MPAs, including community managed areas, are increasing;
- However there is a need for increased enforcement of existing fisheries, MPA and coastal development regulations;
- There is also a greater need for: socioeconomic monitoring to assist in increasing support to address livelihoods; increased support for research and monitoring programs; and the strengthening of national programs that address management in an integrated manner.

### INTRODUCTION

The following chapter is a summary of four national 'Status of Coral Reef' reports that are included in full in the accompanying CD. These reports contain more data and references excluded from this summary.

The coral reefs along the East African coast stretch North to South between latitudes 10°N (Somalia) and 28°S (South Africa), but the reefs are rarely more than 2 km from the coast. This is because the continental shelf is narrow, and the reefs are predominantly fringing, except in Tanzania and Mozambique where there are offshore platforms and one atoll-like reef. Thus these reefs are under the strong influences of the land, as well as a varying climate generated by the northeast and southeast monsoons. The northeast monsoons are characterised by light winds (Kaskazi) inducing warmer temperatures and higher ocean productivity; whereas the southeast monsoons have higher winds (Kusi) lower temperatures, reduced productivity and a higher abundance of benthic algae.



The coasts have coral reefs, mangrove forests and seagrass beds, all reflecting the influence of major rivers that inhibit the reefs but favour the growth of mangroves e.g. the Tana and Athi Sabaki in Kenya, Rufiji and Mkuranga in Tanzania, and the Zambizi and Limpopo in Mozambique. There are extensive coral reefs along the coasts of Kenya (area 620 km<sup>2</sup>), Tanzania (3580 km<sup>2</sup>), Mozambique (1860 km<sup>2</sup>), whereas there are few true reefs in South Africa (40 km<sup>2</sup>). These reefs support major artisanal fisheries and expanding coastal tourism. The reefs and mangroves prevent erosion of the generally sandy coasts.

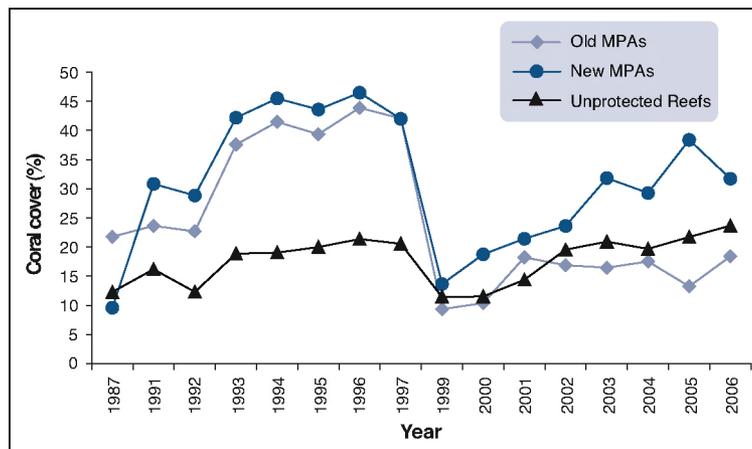
The governments of East Africa have increased legislation and management of these coastal resources through the establishment of marine protected areas (MPAs), acknowledging their economic, food security, nursery, feeding and spawning and coastal protection values. The coral reef ecosystems play important ecological roles as a habitat for many commercial and non-commercial species. Countering these efforts are rapidly expanding populations, growing economic development with land clearing and deforestation, and evidence of climate change damage. There has been extensive ecological monitoring of reefs in Kenya and South Africa, and developing monitoring in Mozambique and Tanzania. Socioeconomic monitoring is expanding rapidly to raise awareness of the importance of coral reefs and support management. This report summarises the major issues along East Africa during the past 4 years, since the Status 2004 report.

## **Kenya**

### **STATUS OF CORAL REEFS 2008**

Several government and non-government organizations routinely research and monitor Kenyan coral reefs and other associated ecosystems: Kenya Marine & Fisheries Research Institute (KMFRI); Kenya Wildlife Service (KWS); the Wildlife Conservation Society (WCS); and Coastal Ocean Research and Development in the Indian Ocean (CORDIO). Most of this activity is focused on MPAs and nearby fished sites. In some sites, there are parallel socioeconomic surveys, especially in Kiunga, on the north coast from Malindi to Mombasa and on the southern coast. The effects of the substantial loss in coral cover during the 1998 bleaching event are still evident in Kenya, although considerable recovery has occurred. A major concern for the future of these coral reefs is whether sea surface temperatures will continue to rise.

The recovery of Kenyan coral reefs after the 1998 bleaching is variable and dependent on many factors. Most reefs are showing recovery, after dropping to about 10% coral cover; such that these reefs now have 18 to 40% cover. However, comparisons between the older fully protected marine parks and unprotected reefs in Kenya show significant differences and despite higher rates of algal grazing (herbivory) in these parks, recovery proceeded more slowly and the community structure showed greater changes in older protected reefs indicating that post-settlement processes had a strong influence on recovery. These findings were contrary to predictions that because protection served to enhance herbivory, recovery in protected areas would proceed more rapidly; both protected and unprotected sites in the study recovered at roughly 2% per year.

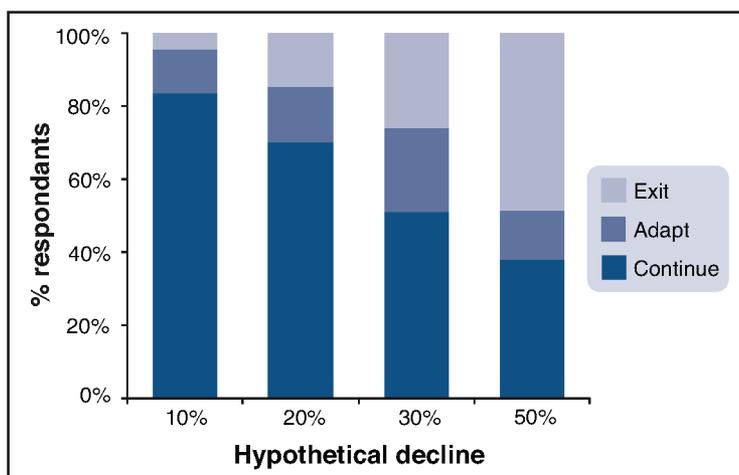


*The effects of the devastation and subsequent recovery after the 1998 coral bleaching are clearly evident. This graph summarises a 20 year study of 7 locations in Kenya: 4 'unprotected reefs' open to fishing (Vipingo, Kanamwatine, Ras Iwatine, Diani); 2 'old MPAs' that were closed in the early 1970s (Malindi and Watamu); and a 'new MPA' (Mombasa) that was closed to fishing in 1991. Before 1998 the protected areas showed increases in coral cover; but all sites lost coral cover during the massive bleaching in 1998. Recovery after 1998 is evident at all sites, but especially in the 'new MPA' site at Mombasa. Note that there may be evidence of similar scale losses prior to 1987. These data on protected and nearby unprotected areas show considerable variability indicating that there are multiple factors affecting recovery (source Tim McClanahan, Coral Reef Conservation Project; this figure with error bars is on the attached CD).*

Coral colony size of 26 different species appears to be decreasing when measured over a 14-year period, including the 1998 bleaching event. The reduction in size is attributed to bleaching and also to fishing pressures. Bleaching can cause partial colony mortality which may regenerate but probably at the expense of reproductive success, therefore resulting in poorer overall reef recovery.

Researchers in Kenya are finding that modelling based on the NOAA satellite products of sea surface temperatures (SST) and degree heating weeks (DHW) is valuable in predicting bleaching, especially if these are complemented with direct temperature measurements. Furthermore they have shown that at least 50% of the bleaching response was due to the species response, with the remainder due to surface temperature variations. Other modelling using more environmental factors indicate that many MPAs in the Indian Ocean are in more vulnerable locations; this modelling should be used to assist in designing MPA networks that will be more resilient to climate change.

Socioeconomic and fisheries studies show that fishers were more likely to abandon fishing when catches were markedly reduced and when their households had a higher material lifestyle of wealth from better jobs. This clearly supports the development of programs targeted at alleviating poverty in the poorest fishing families. The Kenyan government is promoting the mariculture of mud crabs, milkfish and sea cucumbers to cash in on growing international demand. Another program exchanges gear used in coastal fisheries for boats and gear to fish in deeper waters.



*A socioeconomic assessment of the responses of fishers to 4 hypothetical scenarios of declining catch rates (10%, 20%, 30% and 50%) in Kenya. Responses included continue fishing (continue), exit the fishery (exit), and adapt their fishing practices (adapt). The adapt category includes responses such as fish harder, reduce effort, change gear, and change location (From Cinner et al. 2008).*

Kenya has some of the oldest MPAs in the WIO and studies show that it can take more than 37 years for fish population structure, abundance and biomass to fully recover to the status of an un-fished reef. The biomass of fish in fully protected MPAs increases steadily for 10–20 years for fish longer than 10 cm, reaching between 1100 and 1200 kg/ha after fishing is stopped. After about 20 years the fish biomass appears to reach a maximum, although fish population structure will continue to change. Periodic closures, either short or long-term, are of limited value in protecting adequate ecological and biological resources (from McClanahan and Graham 2005).

**Management:** The rapidly increasing and diversifying population in Kenya has resulted in competition and conflict over natural resources. The government recognized the need for integrated coastal management in 1984 and programs have continued with the establishment of the National Environment Management Authority (NEMA). The first Status of the Coast Report was drafted in 2008 as the baseline for management of the Kenyan coast. Similarly, a National Coral Reef Task Force has been developed under the Regional Coral Reef Task Force (CRTF) of the Nairobi Convention. National turtle activities are now also more closely aligned with the Marine Turtle Task Force of the Western Indian Ocean.

Fishing and tourism are the main coastal livelihood sectors but also the most difficult to manage. New legislation has been implemented to enhance management of these sectors and a major Fisheries Policy is awaiting cabinet approval. The policy groups fisher communities into Beach Management Units (BMU) around gazetted landing beaches that are empowered to co-manage their fishing grounds with the Fisheries Department. So far, 30 BMUs have been assisted with training and the development of action plans to serve as models for more than 90 BMUs planned.

Although most forms of destructive fishing are outlawed in Kenya, the use of banned pull seine nets continues. In the last 5 years south coast communities have discouraged the use of these nets leading to an increase in fish catches: this is persuading other communities to stop using pull seines. Similarly, scuba and spearfishing for lobsters and sea cucumbers has also been banned, but there is inadequate enforcement of these regulations. Fisheries management should become more effective because a new ministry for Fisheries Development has been established.

Kenya has assessed the management effectiveness of its 4 marine parks (no-take areas) and 5 marine reserves (restricted fishing areas) covering ~9% of the continental shelf, which are now proving to be effective in preserving biodiversity and managing tourism; but fisheries management is far less effective within the reserves. The assessment recommended increasing enforcement, enhancing stakeholder participation and collaborating more closely with other government institutions to revise management plans based on measurable objectives. All MPAs have management staff, infrastructure and management plans except the Diani-Chale marine reserve (because of historically inadequate consultation with local fishing communities and confusion over regulations in current Reserves). Local fishing communities now have negative attitudes towards establishing new MPAs, impeding Kenyan commitment to the Convention on Biological Diversity to increase MPA coverage.

The Kuruwitu Conservation and Welfare Association of stakeholders (supported by the East African Wildlife Society) voluntarily agreed to close part of their fishing grounds in 2005 to conserve coral reefs and monitor the use of illegal gear. Routine monitoring is showing increases in fishes in these closed areas which is attracting interest from other coastal communities. Grass roots movements of community MPAs, along with the BMUs, are developing in Kenya.

**Capacity Building:** Awareness raising programs are part of the plan to conserve coastal resources via annual events e.g. Marine Environment Day, Wetlands Day and Coastal-Clean-up Day. Training in research and management also continues: the first training course in coral disease monitoring was held in Zanzibar in 2006 through the GEF/WB coral reef targeted and capacity building project. Kenyans have been trained in socioeconomic monitoring since 2001, and in database use (Mombasa, 2007). A certification program coordinated by WIOMSA across the region has registered MPA managers to improve their skills. The principle donors (EU, GEF, USA and the World Bank) are supporting coral reef activities, often through regional organizations like WIOMSA, assisted by WWF, CORDIO and WCS.

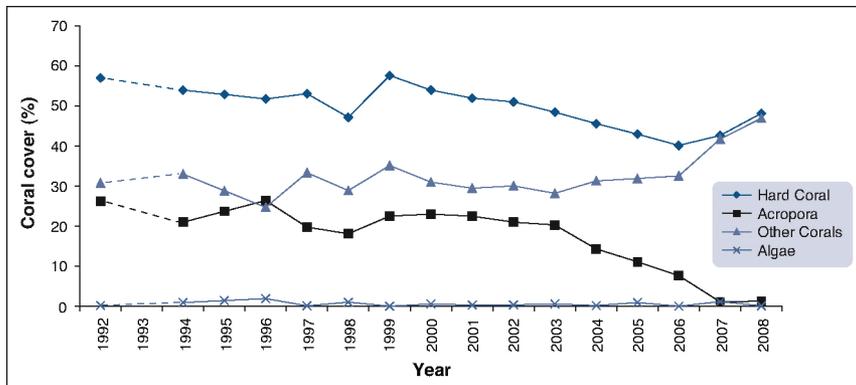
### ***Tanzania***

Like Kenya, the coral reefs of Tanzania support major artisanal fisheries and coastal tourism attracted to the high biological diversity and beauty. These reefs also reduce beach erosion and serve as habitat, nursery, feeding and spawning grounds for many commercial and non-commercial species. Thus they constitute the basis of food security and incomes for many coastal people. This report summarises the major issues regarding Tanzanian coral reefs over the past 4 years (2005-2008).

## STATUS OF CORAL REEFS 2008

Live coral cover continues to indicate good coral recovery potential for most reefs in Tanzania, as observed from combined research projects and routine monitoring. The recovery of reefs off Zanzibar and Dar es Salaam after the 1998 bleaching event, however, was halted by crown-of-thorns-starfish (COTS) outbreaks, especially on Bawe Reef. Further devastation of corals by COTS in Chumbe Marine Sanctuary was slowed through a removal program by the park managers; and another plague has been reported in Mnazi Bay.

Community-based coral reef monitoring has continued in Tanga, Dar es Salaam, and Bagamoyo; and new areas such as Mkuranga, Mnazi Bay, and Kilwa (Songosongo) are being added. Inadequate financial resources prevented monitoring all national monitoring sites identified in 1999.

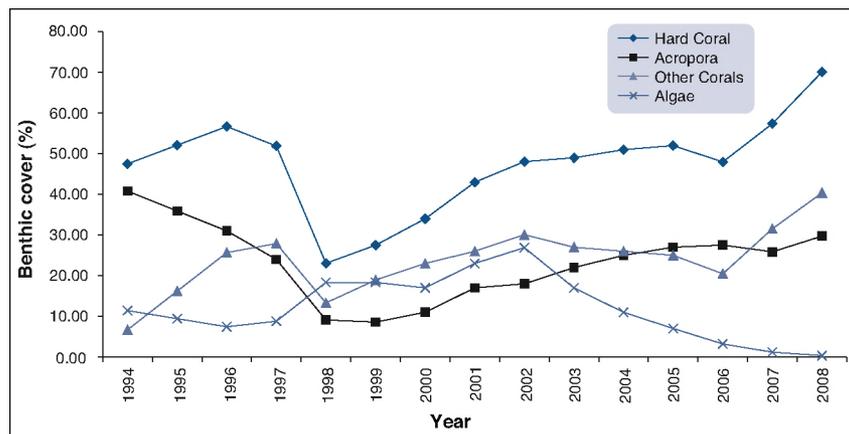


**Cover of hard corals (HC) in Bawe, Tanzania has dropped from around 55% to near 40% predominantly because of massive losses of *Acropora* species due to predation by the crown-of-thorns starfish in 2004. Other corals are now dominant and algal cover is virtually zero. (from Christopher Muhando).**

There has been slow but consistent recovery (especially for *Acropora*) since the 1998 bleaching event on most reefs in Tanzania, especially where populations of COTS have been controlled. Moreover, there has been relatively faster juvenile coral recruitment in 2006 and 2007 in Misali, Mange and Kitutia, all sites that lost coral cover in 1998. Coral cover is increasing on reefs in the Songo Songo Archipelago as well as in Mikindani Bay and Mnazi Bay. The increases in coral recruitment are probably due to more habitat suitability and better environmental conditions than availability of coral larvae.

Reef fish abundance shows declining trends on reefs near urban centres (Zanzibar and Dar es Salaam), and there have also been significant declines on remote and unprotected reefs. However, reef fish abundance is relatively unchanged in most marine parks and conservation areas as enforcement of existing regulations in the Northern Dar es Salaam Marine Reserves appears to be effective in maintaining fish abundance and size. However, community and government monitoring is showing significant declines or possibly collapses in the lobster fishery. Similarly, sea cucumbers are overfished, and the giant triton shell is rarely observed on the reefs but can be found for sale in the markets.

The same threats to coral reefs remain: destructive fishing practices (dynamite and drag nets); over-fishing and pollution (near urban centres); anchor damage (fishing and tourist sites); coral mining for making lime; and sedimentation. There have been no significant coral bleaching events since 1998; however, COTS outbreaks have been observed from 2004 to 2006 on most reefs, specifically in reefs off Zanzibar town and Dar es Salaam. While these outbreaks have diminished in most parts of Tanzania, large populations still remain on reefs off Zanzibar town. The probable reasons for persistence of COTS outbreaks are a combination of over-fishing of natural predators (pufferfish, triggerfish, humphead wrasses, giant triton), eutrophication (mainly through disposal of raw sewage) and natural events.



***Corals have recovered well in the Chumbe Marine Sanctuary after losses during the 1998 coral bleaching event. This recovery has been aided by the removal of crown-of-thorns starfish which damaged Acropora corals on other reefs off Zanzibar. There has been a parallel decline in the cover of algae.***

Coral species richness and diversity has changed on most reefs since the 1998 bleaching event. *Acropora* species have not recovered to abundance levels before the bleaching. *Acropora* abundance has also declined, with possible loss of species in some sites (e.g. Bawe) after COTS devastation. *Acropora* rubble is now covered by coralline and filamentous algae, with *Porites* species providing most of the new coral recruits; these are likely to be dominant in the future. Proliferation of macro-algae and corallimorpharia (specifically *Rhodactis*) occurred on a few reef areas near sewage disposal sites such as Bongoyo in Msasani Bay, Dar es Salaam and Chapwani reefs, Zanzibar. Soft coral and sponge abundance has remained constant (< 5%) except in sites with stronger ocean currents, such as Chole Bay in Mafia. Although some coral disease was present, it is not having a significant impact on Tanzanian coral reefs.

**Management:** Coral reef management is an integral part of integrated coastal management activities being pursued by the Fisheries Division; Environment Division; Marine Parks and Reserves Unit; District Natural Resources offices; Conservation Area authorities; Village Natural Resources Committee; NGOs; hoteliers; dive centres; and fishers. Also there are many institutions involved in coral reef activities including the Institute of Marine Sciences (IMS); Faculty of Aquatic Science and Technology (FAST); Tanzania Fisheries Research Institute

(TAFIRI); Mbegani Fisheries Development Centre (MFDC); Marine Parks and Reserve Unit (MPRU); Fisheries Division and Tanzania Coastal Management Partnership (TCMP); WWF; IUCN; and the GEF-Coral Reef Targeted Research and Capacity Building Project (CRTR), which has sponsored three PhD students. These institutes have concentrated on assessing coral settlement and recruitment; community changes such as coral species richness, diversity, composition and cover after the 1998 coral bleaching event; and relationships between reef fish censuses and artisanal fishing catches. Considerable effort has been directed towards measuring environmental factors that may affect coral reef health such as seawater temperature, nutrients, sedimentation, fishing and coastal erosion. There is also research on how indigenous knowledge can contribute to coral reef management. The Marine Parks and Reserves Unit is working towards establishing a Coelacanth Conservation Area in Tanga

Despite continued education and awareness campaigns, recent socioeconomic surveys show that challenges still remain to encourage compliance with existing coral management regulations. For example, Mafia Island Marine Park and the Mnazi Bay park introduced limestone alternatives but the people prefer live coral for making lime, which also provides a good income. There is an alarming drop in fisheries resources, specifically lobsters, octopus, and sea cucumbers, while fishing effort continues to increase. Destructive fishing by artisanal fishers continues and some are using scuba to collect sea cucumbers from deeper water. Dynamite fishing, halted in the 1990s, has had a resurgence, with increased blasting documented south of Dar es Salaam and in the Tanga area. Over-fishing may be unknowingly or purposely sanctioned by official bodies who risk eventual collapse of fish stocks to avoid immediate social and political conflicts. To eliminate the use of destructive fishing practices, enforcement of existing fisheries regulations has increased and been combined with education and awareness programs to enhance compliance by fishers.

New marine reserves were declared (Government Notice No. 52) in March 2007 to improve coral reef conservation. The new reserves include: Inner and Outer Makatube; Inner and Outer Sinda; and Kendwa, south of Dar es Salaam; the small islands of Nyororo, Mbarakuni and Shungimbili, and the Mafia Archipelago. There are 11 Marine Reserves including Bongoyo, Pangavini, Mbudya, Funguyasini (north of Dar-es-salaam), and Maziwe Island Marine Reserve (in Pangani Tanga), which were gazetted in 1975. Coral reefs off Zanzibar town (Changuu, Bawe, Chapwani and Pange) now comprise the new Zanzibar Stone-Town Conservation Area and consultations with stakeholders are on-going to decide the boundaries and management strategies.

Tanga Coastal Zone Conservation and Development Program activities have been decentralised to enhance local community participation and ownership in coastal resources management. Similar community-based fisheries management principles have been introduced and practiced by Bagamoyo and Mkuranga districts, and committees established to oversee management. The Kinondoni Integrated Coastal Area Management Project activities have been merged with Kinondoni Municipal Council (in the Department of Natural Resources) for similar reasons.

The WWF SeaScape project has assisted in integrating coastal zone management in Rufiji, Mafia and Kilwa districts, to include incentives for alternative economic generation activities to reduce pressure on coastal resources. A specific management effort is tackling the use of live massive corals (mostly *Porites*) to make lime in the Mafia Island, Mtwara and Lindi areas.

**Capacity Building:** Management effectiveness will require considerable investments in research and monitoring training. MSc and PhD students have been sponsored by the Swedish Sida-SAREC project, the GEF coral reef project, IUCN, WWF and WIOMSA. Monitoring training has been upgraded to include coral genera as well as growth forms, and a special training manual is in preparation to standardize protocols. Special training is urgently needed in assessing and mitigating drivers of over-fishing and to encourage better compliance with regulations. There is also a training need in coral reef database and information management to ensure better dissemination of data and information to resource managers.

### ***Mozambique***

The first Coral Reef Management Programme in Mozambique was established in 1999 through the Ministry for the Coordination of Environmental Affairs (MICOA). This report focuses on the essential activities for the management of coral reefs in Mozambique. Since 2004 most activities have focused on improving knowledge, protection and legislation of coral reefs. The coral reefs in Mozambique are recovering from losses in 1998, however, the condition of some remains poor because of damaging fishing practices associated with heavy subsistence fishing. Initiatives are under way to develop new, multiple use MPAs in north, central and south Mozambique that involve local communities in co-management to improve the level of reef conservation in Mozambique.

### **STATUS OF THE CORAL REEFS IN 2008**

Coral reefs in Mozambique form the basis for tropical fisheries supporting about 6.6 million people in 48 coastal administrative districts. The status of most reefs is good, with high cover of hard and soft corals, although the fish population abundance is very low or is dominated by small size classes of herbivore fish.

**Primeiras and Segundas Archipelago:** A chain of coral islands surrounded by fringing reefs in Northern Mozambique: surveys confirm that these are the best reefs in Mozambique, not only in terms of diversity, but also their conservation status. Fish (194 species in 42 families) have been identified as well as 43 hard coral genera and 15 soft corals. This area was proposed as a MPA in 2004 and is now being processed by the Government.

**Santa Carolina Island:** These reefs have been included in the Bazaruto Archipelago National Park and rapid surveys in 2000 and 2007 increased the number of reported fish species from 86 to 106 species and increased families from 24 to 27: the most representative families are Lutjanidae, Haemulidae and Monodactylidae. The Coral Reef Monitoring sub-program has been less active during the last 3 years due to lack of funding. Data collected from the stations of Sencar, Ibo Island and Ponta Maunhane are being analysed.

Seismic studies in the search for oil offshore from the Bazaruto Archipelago National Park under an Environmental Impact Assessment permitted an assessment of the reefs and the impacts of cyclone Favio which hit the park in February 2007. While the 275 km/hour winds caused considerable damage on land, most damage to the nearshore reefs was attributable to an on-going crown-of thorns starfish plague and recreational diving.

**Coral Reef Management:** Planning for new MPAs is underway to include the area between Ponta do Ouro (on the Mozambique and South Africa border) and Inhaca Island. The Archipelago of Primeiras and Segunda will include protection for waters out to 3 miles off the coast to protect some of the best coral communities in central Mozambique. The planning by the Government of Mozambique involves the Ministry for the Coordination of Environmental Affairs (MICOA) and Ministry of Tourism (MITUR). Mozambique is developing a national conservation policy lead by the Ministries for the Coordination of Environmental Affairs and Tourism. After the agreement was obtained from the major stakeholders during considerable consultation, the conservation policy is being analysed by Council of Ministers. A multi-national project, TRANSMAP, has also recently been completed, to provide information to plan trans-frontier MPAs between Mozambique and Tanzania and South Africa.

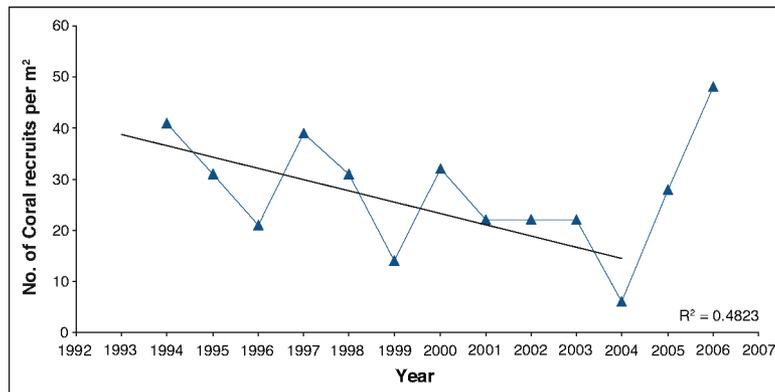
**New legislation to protect coral reefs:** In 2006, the Council of Ministers approved a regulation called "Regulation for the Pollution Prevention and Protection of the Coastal and Marine Environment (Decree 45/2006)" to protect coral reefs. Collection of corals is forbidden as are all other activities that damage coral reefs.

### ***South Africa***

Corals are only found in north-east South Africa in a World Heritage site, the IsiMangaliso Wetland Park (IsiMWP), in the Delagoa Bioregion. These are marginal coral communities at the extreme south of coral distribution; however the reefs are rich in biodiversity. There are 90 species of hard coral, 40 species of soft coral and at least 30 species each of ascidians (sea squirts) and sponges. The reef communities consist of a mixture of tropical and temperate Indo-Pacific fauna and include numerous endemic invertebrate and fish species. The coral communities do not form true coral reefs but grow as a veneer on sandstone reefs, with the soft corals, rather than hard corals, dominating most of the reefs. The soft corals (Alcyonacea) tolerate the local conditions better and form extensive carpets on the flat, turbulent reef tops.

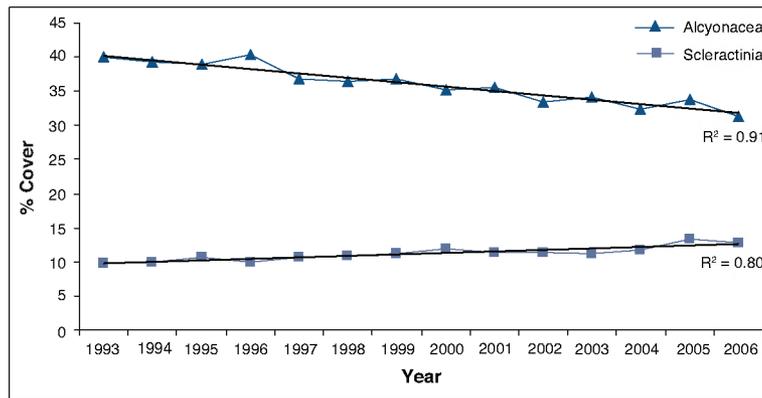
The reefs cover only 40 km<sup>2</sup> in area in three complexes with some scattered reefs in between. Corals grow from the shallowest (8 m) depth down to 27 m. These reefs have been zoned for recreational use according to their carrying capacity and the sensitivity of their coral communities to damage. The geological, coastal and socioeconomic data and management plans have been combined into an interactive, CD-ROM-based GIS model for improved park planning and management.

Long-term reef monitoring commenced in 1993 along with temperature logging. Sea temperatures rose by 0.15°C per annum up to 2000, but have subsequently been decreasing by 0.07°C per annum. Very little bleaching occurred during the 1998 bleaching event, unlike elsewhere in East Africa. However, some bleaching occurred during an extended warm period in 2000 when peak temperatures appeared to reach a regional coral bleaching threshold. While there has been relatively little bleaching thus far, coral recruitment appears to have declined until 2004 but appears to be improving again (the temperature data and analyses of Schleyer et al. 2008 are available on the attached CD).



***Coral recruitment success declined significantly until 2004, but there has been a noticeable improvement in 2005 and 2006 (from Schleyer et al. 2008).***

Monitoring has shown changes in community structure with reduced soft coral cover and increased hard coral cover. Overall, there has been a 5.5% drop in coral cover. Therefore, while warming may be encouraging hard coral growth, at the expense of the soft corals, if global warming persists, bleaching and ocean acidification may further diminish coral cover. The South African high latitude reefs may thus provide a model to study the effects of global climate change at the extremes of coral distribution before they become evident in the tropics.



***Long-term changes in soft coral (Alcyonacean) and hard coral (Scleractinian) cover measured at the South African long-term coral monitoring site from 1993–2006 (from Schleyer et al. 2008).***

### EAST AFRICA REGIONAL OVERVIEW

A regional study of reefs from Kenya to Madagascar showed that the highest diversity of corals occurs in warmer seas with the greatest fluctuation in temperatures between seasons; this appears to give corals the ability to survive severe bleaching events better than reefs growing in more stable temperature regimes. Thus the reefs most resistant to increased temperature are in Tanzania, Comoros and northern Madagascar, suggesting these are priority conservation reefs.

Research also showed that modelling based on the NOAA satellite products of SST and DHW is valuable in predicting bleaching, especially if these are complemented with direct temperature measurements. Furthermore, it was shown that at least 50% of the bleaching was due to the species response and the remainder to anomalous sea surface temperatures. Other modelling using more environmental factors indicates that many of the MPAs in the Indian Ocean are in more vulnerable locations; this modelling should be used to assist in designing MPA networks that will be more resilient to climate change.

Modelling also indicates that coastal communities dependent on coral reefs can adapt to climate change by: 1) protecting large areas of ecosystems; 2) transforming and adapting socio-ecological systems; 3) building capacity to cope; or 4) using government assistance to reduce dependence on natural resources. The Seychelles, Maldives, and parts of Kenya have the adaptive capacity to mitigate against environmental changes; southern Indian Ocean countries, however, had lower vulnerability and a mix of social adaptive capacity. Current conservation capacities and actions appear to be inadequate to meet the challenges of climate change in the Indian Ocean.

## RECOMMENDATIONS TO IMPROVE CORAL REEF CONSERVATION

- Research and monitoring results showed that recovery after the 1998 bleaching was slow on some reefs and that fishing, COTS infestations and post-settlement factors are affecting recovery. Management action should therefore include control of fishing activities, especially destructive fishing, pollution and other factors that could increase stresses on reefs. This will require more integrated programs that involve all the key management institutions and stakeholders of coral reefs, especially to enforce regulations.
- Findings from socioeconomic studies also showed that willingness to leave the fishery, amongst the fishers with the lowest socioeconomic status, increased with expanded livelihood opportunities. Programs that target alternative fisher livelihoods would therefore have a positive impact on reefs by reducing fishing effort.
- Research also showed that reefs in southern Kenya, Tanzania, northern Mozambique across to northern Madagascar are not only high biodiversity areas, but showed better resilience after the 1998 bleaching event. This indicates that these reefs may be less vulnerable to climate change and should be high priority sites for conservation.
- The Regional Action Plan recommends national coral reef programs: these have not been established in many countries, hence progress in strengthening national coral reef activities and integrating these into coastal management should be initiated.
- Although more than 72 MPAs have been established in the region, many are not effectively managed and this needs to be addressed. In addition, different types of MPAs, including community managed areas, should be piloted to address the needs of coastal communities.
- There is still low capacity for doing research in many countries and this needs strengthening. Regional projects such as those funded through WIOMSA can help fill this gap but require more support.
- There is still a need to strengthen the management of coastal and marine resources, especially through better enforcement of current fisheries, MPA and coastal management regulations.

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## 7. STATUS OF THE CORAL REEFS OF THE SOUTH-WEST INDIAN OCEAN ISLAND STATES: COMOROS, MADAGASCAR, MAURITIUS, REUNION, SEYCHELLES

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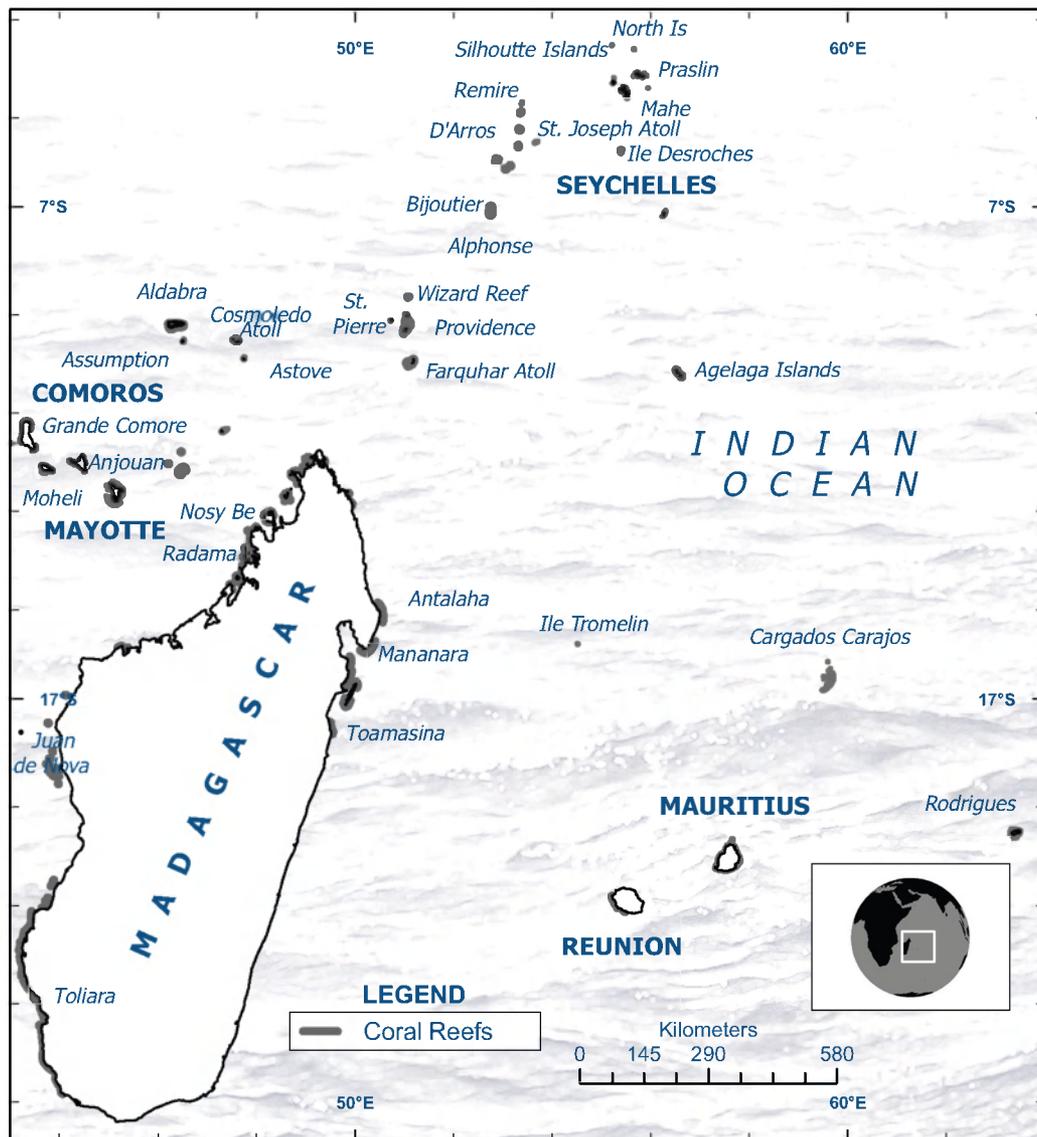
### ABSTRACT

- Many reefs are recovering well from 1998 mass coral bleaching damage with all countries having some areas with good coral cover, and other areas with slow or little coral recovery;
- Mean live coral cover has continued to increase on some reefs of the Seychelles and Comoros, but has decreased on some reefs in Mauritius and La Réunion;
- The stresses causing low coral cover are mostly from human activities, such as trampling, pollution, chronic sedimentation and over-fishing;
- Cyclones and coral bleaching are the most important natural stresses damaging the reefs, with some bleaching recorded annually since 2000 in parts of the region;
- There is little information on the status of seagrass and mangrove areas in many countries, due to poor or no monitoring programs;
- Most countries have no active socioeconomic monitoring, and ecological and socioeconomic monitoring results are not reported regularly to reef managers;
- Recommendations include increasing efforts to reduce human impacts and increasing monitoring within and outside MPAs, especially on more remote reefs;
- Cooperation between the regional network and global or regional programs is needed to increase awareness in coastal communities of coral reef issues, and to make monitoring of coral reefs financially sustainable with regular mechanisms to feed ecological and socioeconomic monitoring results into management processes.

## INTRODUCTION

The SWIO node of the Global Coral Reef Monitoring Network consists of countries of the Indian Ocean Commission (COI) which includes the Comoros, Madagascar, Mauritius, La Réunion (France) and the Seychelles. Most of these countries have significant areas of coral reefs, which play an important role in the socioeconomic well-being of their coastal communities. Monitoring throughout the node uses GCRMN methodologies, but with some modifications made in the Seychelles.

The **Comoros** has 430 km<sup>2</sup> of reef area, with those on the Comoros volcanic islands being young and fringing the newer islands. The AIDE (Association d'Intervention pour le Développement et l'Environnement) NGO, with support from the Indian Ocean Commission, has conducted coral



reef monitoring using protocols recommended by the GCRMN since 1998 on 3 islands: Grande Comore; Moheli; and Anjouan. Monitoring of barrier reefs of Mayotte, which is under French administration, is carried out by the Agriculture and Forestry Department. Socioeconomic monitoring is currently conducted under CORDIO supervision and should be cross-analysed with ecological data through GIS tools to assist in adaptive and integrated management of the reefs and associated resources.

**Madagascar** spans 14° of latitude, harbouring over 3500 km of coral reefs in widely differing oceanographic settings. The most extensive reefs are found in the north-east, north-west, and south-west coasts, and have the highest richness of coral species in the central and western Indian Ocean. Almost all accessible reefs are exploited by traditional artisanal fisheries with fishing effort increasing considerably over the past decade due to rapidly expanding commercial demand from fisheries enterprises. The growth of fishing effort has coincided with diversification of the range of species targeted by fishers and collectors. In addition to the negative impacts of unsustainable and largely unmonitored biomass removal, reef degradation is attributable to the chronic impacts of hyper-sedimentation from river discharge as well as organic enrichment and pollution of coastal waters. Cyclonic activity in Madagascar is high, with severe localised damage to coral reefs attributable to cyclones and tropical storms on an approximately annual basis.

**Mauritius** has a coastline of 200 km with 243 km<sup>2</sup> of lagoon area enclosed by 150 km of fringing reef that almost completely surrounds the island, except at major river mouths and on the south and west coasts. Mauritius has rich coral diversity with a total of 159 hard corals in 43 genera. Recent coral bleaching in 2003–2004 affected some corals; however the reefs have since recovered and new recruits are increasing, especially on the reef slopes. The back reef is mostly dominated by branching and tabular *Acropora*, whereas encrusting corals dominate the fore-reef. Algae have been observed seasonally and a few soft corals and other colonial animals such as zoanthids are relatively common. The physico-chemical and bacteriological parameters are within the Coastal Water Quality Guidelines at all sites. The major threats to coral reefs are cyclones, coral diseases, crown-of-thorns starfish, coral bleaching and human damage from extensive coastal development, land-based pollution, sewage outfalls and anchor damage.

The Mauritian island of **Rodrigues** is surrounded by a fringing reef, which forms an almost continuous band approximately 90 km long. The reef encloses a shallow lagoon of 240 km<sup>2</sup> (twice the area of the island). The reefs are covered mainly by hard corals, with *Acropora* species dominant on both the reef flat and slope. Coral cover on the reef slopes around Rodrigues is relatively high and the reefs are healthy. Lower coral cover on the more heavily impacted reef flats is attributable to coral bleaching and fishing pressure (particularly trampling by octopus fishers).

**La Réunion** has 12 km<sup>2</sup> of fringing and platform reefs, restricted to the west and south of the island. Since the 1980s, these reefs have come under increasing pressure from both human and natural factors such as excessive trampling on the reef flat, over-fishing, excessive sedimentation from the land, cyclones and coral bleaching (which has been recorded annually from 2001 to 2005). There are 14 monitoring sites (7 on the reef flat, 7 on the reef slope) in 4 distinct sectors along the west and south coasts at St. Gilles, St. Leu, Etang Salé and St. Pierre which include annual monitoring of bottom communities and reef fishes. The site at St. Gilles

has been monitored since 1998. A Marine National Reserve was created along 40 km of the west coast in 2007 but is not fully operational due to delays in implementation caused by conflicts between traditional fishermen and the authorities, inadequate planning and poor integrated coastal zone management.

The **Seychelles** islands have an estimated 1690 km<sup>2</sup> of coral reef, which is about 13.1% of the total coral reef area of the Eastern Africa and the South West Indian Ocean islands. The inner islands, where most people live, have only 40 km<sup>2</sup> of coral reef, and fishing remains the most important economic reef activity. Reefs around the granitic islands are heavily fished and yield around 50% of the total annual demersal catch. In 2003, it was estimated that 19% of visitors to the Seychelles participated in scuba diving and 65% in some form of snorkelling activity. Prior to the mass coral bleaching event of 1998, the coral reefs of the Seychelles were described as healthy with high coral cover, typically 60–90%. Coral cover after the bleaching event was reduced to less than 5% at most locations around the granitic islands. Between 2000 and 2004 mean live coral cover increased from 3.7% to 10.2% and is still increasing. Primary threats to coral reefs include dredging and reclamation, sedimentation, excessive fishing pressure, coral diseases, invasive species and climate change associated with global warming.

## STATUS OF CORAL REEFS

There are two contrasting trends in the status of the reefs of the South West Indian Ocean. Reefs to the north (Comoros and Seychelles) that were seriously damaged in 1998 are showing slow but steady recovery, whereas reefs in the south that missed most of the bleaching losses are either stable (La Réunion) or declining (Mauritius and Rodrigues).

In the **Comoros** mean live coral cover at the monitoring sites was 77.5% in 1997, a year before the mass coral bleaching event. By 2002 mean live coral cover had dropped to 39%, but since then there has been a significant positive trend ( $R^2 = 0.96$ ) and in 2007 cover was 66%; similar to the pre-bleaching level. Live coral cover has returned to pre-bleaching levels at many sites in the 10 years since the 1998 mass coral bleaching, and over 70% live coral cover is now present on the reef along Wani on Anjouan, Mitsamiouli at Grande Comore and Walla at Moheli. Some sites such as Bimbini at Anjouan and Chindini at Grande Comore are showing poor recovery and have low coral cover (about 24%). These reef sites are under high pressure from over-fishing, sedimentation and trampling. In the Moheli Marine Park the coral reefs are in good health with mean coral cover ranging between 50% and 72%. On unprotected reefs at the same island, such as Fomboni and Hoani, mean live coral cover is <30%. Minor coral bleaching (1–10%) was recorded in 2004 and 2005; however, the corals and reefs rapidly recovered, especially at sites with low human pressures.

There are few quantitative data for **Madagascar** to document coral reef responses to the bleaching events of 1998, 2001 and 2002 that devastated the reefs. With the exception of moderate bleaching on the north-eastern reefs in 2005, no subsequent widespread bleaching-related coral mortality events have been recorded in Madagascar over the past 6 years. Coral reef monitoring in the south-west started in 2003, and additional sporadic surveys have been carried out at sites in the north since 2004, where the reefs are generally considered to be in better condition. While annual reef assessments in the south-west provide an insight into reef condition and recovery responses, the absence of long-term quantitative reef assessments throughout the country means that the health and status of Madagascar's vast coral reef

systems cannot be determined. Madagascar's marine and coastal protected area network is currently being expanded, thus it is critical that reef monitoring efforts be enhanced to provide better information on ecosystem status, recovery and resilience to protected area managers and decision makers.

Monitoring in the south-west near Andavadoaka encompasses fringing, barrier and patch reef sites which experience a range of fishing pressures. Most seaward fringing and barrier reefs in this region have undergone a phase shift from coral to algal-dominated communities. Typical seaward reefs in the region have <20% coral cover, with high or dominant levels (35–80%) of turf and macro-algae, particularly *Lobophora*, *Dictyota* and *Turbinaria* species. The dominant corals are faviids, poritiids, agaricids and mussids at all depths and on all reef types on an eroded coral framework, whereas branching *Acropora* species were previously dominant. The exposed seaward slopes have been planed smooth by wave action and hardened by encrusting turf and calcareous algae. Conversely, many sheltered fringing reefs and lagoonal patches consist of loose unconsolidated coral rubble. This rubble and the high cover of seaweeds are probably limiting reef recovery by inhibiting the recruitment of hard coral larvae.

Since 2004 coral cover at heavily-fished near-shore sites has remained stable at 5–10% showing no recovery trends; similarly seaweed and algal turf cover remains high at 60–80%, showing no evidence of decline. Although these heavily-degraded reefs have not recovered, a number of less-exploited sites have shown substantial improvement in coral cover. Of note are several deep lagoonal patch reefs where coral cover has increased from about 30% to 70% between 2004 and 2008, accompanied by a reduction in algal cover from ~50% to ~20%. Clear differences in recovery between heavily-exploited and less exploited reef sites suggest that the reefs have significant resilience and recovery potential but this may be inhibited by high fishing pressure. This points to the tremendous potential for management strategies that prioritise the reduction of algal dominance on the reefs. Reducing the rate of removal of algal grazing fishes and decreasing terrestrial nutrient runoff could improve reef resilience against future disturbance events by enhancing coral recruitment and growth.

In **Mauritius**, there were no signs of coral bleaching between 2005 and 2007 at permanent back reef and fore-reef monitoring sites. In 2007 mean live coral cover was >50% at 5 of the 17 sites, 38% at 3, <38% at 7, and <2% at 2 sites. Algal cover was <20% at 13 of the 17 sites and was >30% at 3 sites. There has been a gradual decline in live coral cover at the 4 fore-reef sites, which is attributed to natural and human factors. Bleaching in 2003–2004 also contributed to reef degradation. Not all fore-reef sites were monitored in 2001 and 2006 which explains the lower coral cover levels in the graph presented below. There has been an increase in abundance of invertebrates (sea-urchins) at sites where bare rock cover was highest. Holothurians (sea cucumbers) were commonly recorded at back reef stations while their distribution was sparse on the fore-reef. Territorial fish species (damselfish, surgeonfish and butterflyfish) were the dominant species recorded. The results of the water quality surveys at the sites have not shown any negative impacts and are within the standard norms. A detailed study on the effect of coral bleaching on the reef of Mauritius was carried out in 2006 with funding from CORDIO.

In the amended Fisheries and Marine Resources Act 2007 regulations prohibit the removal of coral and sea shells. A long-term monitoring programme is on-going in the Blue Bay and Balaclava Marine Parks and data are routinely collected on benthic cover, reef fishes, macro-

benthos and water quality. Activities in the parks are regulated by the MPA Regulations. The Blue Bay Marine Park was declared a Ramsar Site (a wetland of international importance) in 2008.

In the Mauritian island of **Rodrigues**, 9 fringing reef sites have been monitored since 2002: Riviere Banane, Passe Armand, Grand Bassin and Ile aux Fous (reef flat and reef slope sites); Passe Cabri, Trou Blanc and Passe L'Ancre (reef flat only); and Passe Demi and North Ile aux Sables (reef slope only). Mean live coral cover is high on reef slopes at Riviere Banane, Grand Basin and Ile aux Fous (>45%), but is low at Passe Demie, North Ile aux Sables and Passe Armand (<30%). Dead coral cover is low at all sites suggesting that they are generally healthy. Increases in the red macro-algae, *Asparagopsis taxiformis*, was recorded at some sites during October 2004 but cover returned to low levels the following summer, suggesting a natural phenomenon. Coral cover was low at all reef flat sites (<30%). A large increase in dead coral cover was seen in March 2002 at Passe Armand and Grand Bassin, and again in October 2005 at Passe Armand, Trou Blanc and Ile aux Fous: these increases were due to coral bleaching. The fish community at all sites tended to be dominated by damselfish. Emperors, snappers, trevally and groupers were rare or absent and no triggerfish (ballistids) were observed at any site. The lack of large fish predators suggests fishing pressure is high. Sites have shown no obvious variation over time and occasional differences are due to large shoals of surgeonfish and fusiliers. Macro-invertebrate densities were low on the reef slopes with the urchin, *Echinometra mathaei*, dominating all reef slope and flat sites except Passe L'Ancre. There were temporal variations in the abundance of *E. mathaei* on the reef slope at Passe Armand and North Ile aux Sable and a general increase in urchin numbers from October 2005 on the reef flat at Rivière Banane, Passe Armand, Grand Bassin and Trou Blanc. The abundance of these urchins may be due to intense fishing pressure and the removal of predators, especially triggerfish (ballistids).

The coral reefs of **La Réunion** are seriously threatened with around 50% of the reef area considered to be degraded. The status of coral reefs has remained relatively stable since 2004, with no significant changes or observed trends. At Alizés Plage in the St. Pierre sector and Planch'Alizés in the St. Gilles sector the coral communities are characterised by disturbed areas with high dominance of opportunistic sub-massive corals such as *Montipora circumvallata*, *Porites (synarea) rus* and *Psammocora contigua*. These sites have medium mean coral cover (40–50%) and are less sensitive to perturbations such as algal colonisation, coral bleaching and cyclones and have remained stable since their monitoring started. However these coral communities are generally less favourable as habitat for reef fishes and only a few omnivorous fish were observed.

The less disturbed stations (Trois-Chameaux in the St. Gilles sector, La Corne and La Varangue in the St. Leu sector, Bassin Pirogue in the Etang-Salé sector and Ravine Blanche in the St. Pierre sector) have highly varied benthic populations dominated by branching and digitate *Acropora* sp. corals. These sites are very sensitive to coral bleaching and colonisation by turf algae. As a result, coral cover has varied since monitoring started, with periods of good coral growth alternating with major mortality events, which were simultaneous in all 4 sectors in 2003 and 2004. The cause of wide spread coral mortality on the reef flats at La Réunion varies and includes elevated sea surface temperature, freshwater input and cyclones.

The status of the benthos on the reef slopes has undergone two different trends. Firstly, a continuous decrease in mean live coral cover at 3 sites: coral cover dropped from 56.8% in 1998 to 29.8% in 2007 at Trois-Chameaux, from 48.8% in 2000 to 26.3% in 2007 at Planch'Alizés, and from 57.8% in 2000 to 37.3% in 2007 at Etang-Salé. This decline is probably due to pollution from the catchment area. Secondly, coral cover has been stable at the St. Leu and St. Pierre monitoring stations: coral cover on the reef slope at La Corne in the St. Leu sector has been around 74% since 1999. The reef slopes in the St. Pierre sector at Ravine Blanche and Alizés Plages have high coral diversity and do not appear to be adversely affected by sedimentation from the nearby river.

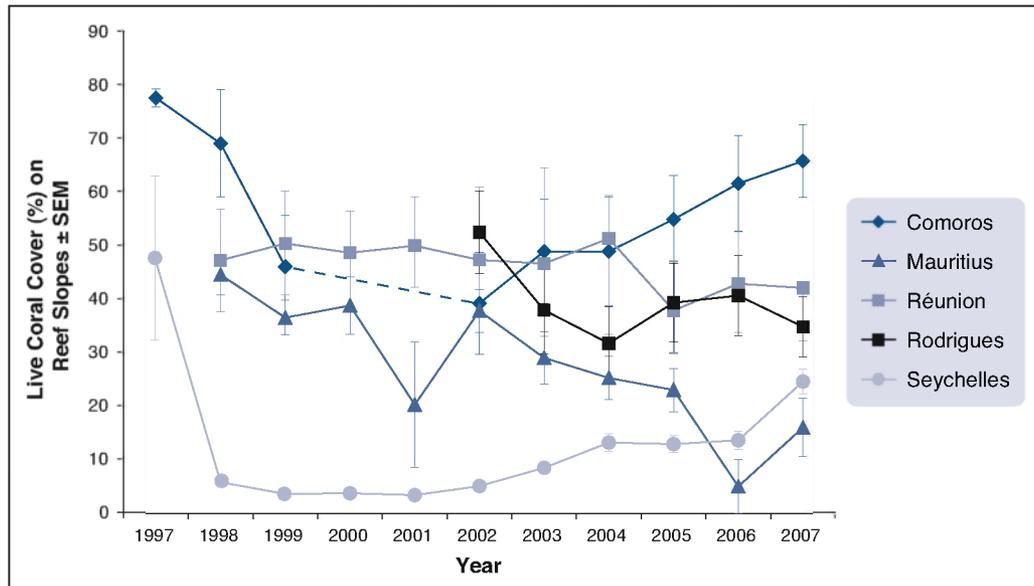
The fish populations on the reef slopes are characterised by low abundance of high trophic level species such as the piscivores. Herbivores are generally the most dominant trophic group observed. The population structure of damselfish differs between sites. In areas where *Acropora* have been heavily over-grown by algae, *Stegastes* sp. are common, whereas *Chromis* sp. and *Dascyllus* sp. are more dominant at stations with healthy coral growth.

In the **Seychelles** inner islands, corals at the north of Mahé Island and in the Curieuse Marine National Park indicate rapid recovery to a new mean cover of 24.6% by the end of 2007. However, recent surveys across the entire inner island group suggests that recovery is highly patchy, with some reefs exhibiting >20% coral cover while others have less than 5%. Mean live hard coral cover across the entire inner islands was 3.7% in 2000, 10.2% in 2004 and 11% in 2007.

In January 2005, live coral cover on the fore-reef slope of the Amirantes islands of Marie-Louise, Boudeuse, Poivre and Alphonse ranged from 7 to 26% and was dominated by *Porites* and *Pocillopora*. At Alphonse between 1999 and 2003 there was good coral recovery following the bleaching, with average live coral cover increasing from 10% in 1999, to 12–17% in 2001–2002, and to 23% in 2003. At the southern-most islands of Aldabra, Astove and Assumption recovery was minimal in the period between 1999 and 2006 with the exception of St. Pierre Island where heavy recruitment of *Pocillopora eydouxi* has increased coral cover by 18%.

Coral recruitment on the granite based reefs of the inner islands is much better than on the carbonate reefs, with a strong linear increase in the number of corals recruiting onto the granitic reefs ( $R^2 = 0.984$ ) and a weaker trend on the carbonate reefs ( $R^2 = 0.438$ ). Levels of coral recruitment are greater in shallow areas than in deeper zones.

The trends for the coral reef fish population are less clear between 2002 and 2006: butterflyfish (Chaetodontidae) populations appear to be stable; damselfish (Pomacanthidae) show a gradual linear increase ( $R^2 = 0.68$ ); 3 main herbivore families show signs of decline. The same downward trend was also observed in the main target fish, the snappers and groupers (Holocentridae, Lethrinidae, Lutjanidae and Serranidae). There have been no significant differences in fish-species diversity between 2002 and 2005 on Aldabra, Assumption, Astove, and St. Pierre. The reef fish densities at these locations were all high and similar to one another, indicating equally productive systems with low fishing pressures.



*This graph shows trends in average live coral cover on the reef slopes in the South-West Indian Ocean Island States collected from a limited number of long-term monitoring sites. Following the bleaching event of 1998, coral cover in the Seychelles dropped from about 50% to less than 5%, but is now slowly recovering. The data above are from the north-west coast of Mahé and the Curieuse Marine National Park which have reasonable coral recovery, but recovery has been less rapid elsewhere on the inner islands. In contrast, there has been about a 70% decline in coral cover in Mauritius since 1998, note that in 2001 and 2006 not all reef slope sites were monitored.*

#### STATUS OF MANGROVE, SEAGRASS AND FISHERIES

The associated ecosystems of seagrasses and mangroves have been poorly studied in **Comoros**. Aerial images of coastal habitats have been used to inventory seagrass species in parallel with species assessments at some sites. Seagrass beds are well developed in the Bimbini area of Anjouan Island, at Mitsamiouli and Chindini-Malé in Grande Comores and Itsamia in Moheli, with 9 of the 12 Indian Ocean species being found in the Comoros. The main threats to seagrass beds are over-fishing and sedimentation from soil erosion. Mangroves are very well established in the Nioumachoua-Wallah area in Moheli; Bimbini in Anjouan; Ouroveni, Domorni, Iconi and Voidjoou in Grande Comores: 8 species are known from Comoros. Human damage to those coastal ecosystems is mainly due to artisanal fisheries which involves 8000 fishermen and 4000 traditional boats. About 6000 of the potential 20 000 tons of pelagic stock are exploited of which 900 to 2700 tones are coastal pelagic. About 450 to 1350 tons of demersal fish are exploited.

Mangroves and seagrass beds, along with associated estuarine mud flats, are integrated along the 1500 km coral reef system which dominates the western side of Madagascar. They have profound implications for the ecological diversity as well as the wellbeing of the human populations in this region. Seagrass species diversity, distribution, abundance and status in Madagascar are largely unknown. Preliminary studies in the Andavadoaka region have identified *Thalassodendron ciliatum*, *Thalassia hemprichii*, *Cymodocea serrulata*, *Syringodium*

*isoetifolium*, *Halophila ovalis* and *Halodule beaudette*, with studies in the Ranobe region adding *Cymodocea rotundata* and *Halopphilia stipulecea* to this list. Increased levels of human waste, coupled with a rise in non-biodegradable disposable products and augmented levels of fishing could initiate substantial die-back within local seagrass beds. These effects will be amplified by increases in development and tourism.

Madagascar's mangrove forests occur almost exclusively on the western coast with an approximate area of 3300 km<sup>2</sup>. Recent data show that between 1975 and 2005 there was an overall loss of 7% of mangrove forests leaving a total of ~2797 km<sup>2</sup> in 2005. (Note that the extent of mangrove forest actually increased by 212 km<sup>2</sup> from 1975 to 1990 but decreased 528 km<sup>2</sup> in the 15 years from 1990 to 2005). While no detailed data are available on the extent of mangrove forests in 2008 the main threats remain the same – conversion to agriculture, logging, conversion to aquaculture and urban development. As such, it is likely that the decrease has continued. There is some evidence that coastal fisheries are under pressure, with the average size of landed individuals significantly lower than documented average species sizes.

In **Mauritius**, the two species of mangroves are protected under the Fisheries and Marine Resources Act. Since 1995 the Ministry of Fisheries has embarked on a programme of mangrove propagation to reforest denuded areas of the coast. To reduce fishing pressures in the lagoon, fishermen are now being encouraged to fish outside lagoon areas and use fish aggregation devices in open water.

Mangroves (*Rhizophora mucronata*) in **Rodrigues** have been introduced to prevent soil erosion in some bays of the island but there have been no follow up studies. Only 2 species of seagrass (*Halophila stipulecea* and *Halophila ovalis*) are known from the lagoon of Rodrigues. Studies of the lagoon fishery in Rodrigues indicate over-fishing shown by declining fish catches and in predatory species such as the emperor, *Lethrinus harak*. The designation of 4 marine reserves and an MPA in Rodrigues will help to protect the healthy reef slopes from future impacts and aim to facilitate recovery of the degraded reef flat areas and the lagoon fishery.

Mangroves in the **Seychelles** are not used commercially and the mangrove forests are in a generally healthy state. The most prolific stands of mangroves in the Seychelles occur in the lagoon of Aldabra Atoll and inside the lagoons of other outer islands. In the inner islands, there has been a proliferation of mangroves in the lagoons created by the land reclamation along the east coast of Mahé. The mangrove forest in the Curieuse Marine National Park is now under threat and many trees have started to die because of increased exposure to wave action since the wall protecting the forest was demolished during the 2004 tsunami. Threats to mangroves include small scale land reclamation for construction. The seagrass beds of the Seychelles are extensive, especially in the outer islands, and are in a healthy state. The coastal fisheries are under pressure, such that there are indications of over-fishing of the red snapper (*Lutjanus sebae*). The sea cucumber and lobster fisheries are also being tightly regulated to prevent over-exploitation.

There are no mangroves on **La Réunion**.

### STATUS OF CORAL REEFS ON SMALL FRENCH ISLANDS IN THE WESTERN INDIAN OCEAN

There are 5 remote, protected islands in the Mozambique channel (Europa, Bassas da India, Juan de Nova, Glorieuses) and central western Indian Ocean (Tromelin), that are administrated by France, specifically the TAAF (Terres Australes et Antarctiques Françaises) authority. These islands are recognised as hot spots for conservation of turtles and seabirds which have been studied in detail; however the coral reefs were poorly studied until 2002 – 2005 when scientific expeditions were undertaken within the French coral reef initiative (IFRECOR) to assess the health and biodiversity status of all French reefs. This included shallow water mapping that revealed a coral reef area of 493 km<sup>2</sup>, within the French EEZ of 640 400 km<sup>2</sup>. These expeditions established 11 monitoring stations as contributions to GCRMN and Reef Check initiatives and temperature data loggers were installed at Europa, Juan de Nova and Glorieuses as these islands are located on the route taken by warm water masses that have caused coral bleaching.

The benthic communities are dominated by *Halimeda* algal banks, which confirm observations from 1977. Coral cover is greatest on the windward sides of the reefs (25–60%), which are dominated by soft corals, while *Acropora* species represent less than 5% of the hard coral cover on these outer slopes. The fish populations showed high species richness and carnivore biomass, which confirmed the positive benefits of their protection. Associated mangrove and seagrasses ecosystems were also identified for Europa and Glorieuses. There are significant and healthy mangrove forests in the lagoon of Europa which are important for bird, turtle and fish populations.

There are no direct human pressures on these coral reefs as the islands are nature reserves. Thus, the threats affecting these remote islands have mostly been 'natural' in origin, such as the 1998 massive bleaching mortality of coral reefs in the Mozambique Channel, or crown-of-thorns starfish plagues observed on the outer slopes of Europa in 2002. Oil spills are considered a potentially serious threat for the coral reefs and associated intertidal areas as the Mozambique Channel is the main route for tankers (from Thierry Perillo, thierry.perillo@taaf.fr and Jean Pascal Quod, pascal.quod@arvam.com).

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## CONCLUSIONS

Coral reef monitoring, which started almost a decade ago in many countries under the GCRMN umbrella, has shown that coral reefs in the region are undergoing both recovery as well as further degradation. All countries have reefs that are recovering well including reefs that have been slow to recover or are degrading. In many cases, the human pressures such as chronic sedimentation, over-fishing and pollution are the major factors limiting reef recovery. Mild coral bleaching events, which have been recorded annually since 2000 in one or more countries, have caused some coral death and retarded recovery at many reef sites. Besides GCRMN, other monitoring programs have been implemented by local scientists from the member countries, and other survey initiatives such as Reef Check have been implemented by dive clubs, NGOs, etc. There is an information gap on the status of seagrass and mangrove habitats in all countries. There is no active socioeconomic monitoring in most countries and generally there has been little input of monitoring results (ecological and socioeconomic) in operational management. In addition, a lack of dedicated funds for national and regional monitoring programs has also reduced the flow of current coral reef information and in many countries there has been a reduction in the number of sites being monitored.

## RECOMMENDATIONS

- Efforts should be made throughout the region to lower human pressures on coral reefs. Human impacts and coral bleaching episodes are the 2 main threats to the recovery of coral reefs in the region;
- There should be a balance between monitoring sites within and outside MPAs to better evaluate the impact of protection on the recovery of coral reefs in the region;
- Biodiversity programs should be initiated to explore and document coral reef biodiversity at less studied reef sites in the region (e.g. Southern Seychelles, St. Brandon and Agaléga (Mauritius), Iles Eparses (France)).
- Monitoring of seagrass and mangrove areas should be initiated;
- Socioeconomic monitoring in coastal communities should be increased and the results should be incorporated into the management of coral reefs and MPAs in the region;
- The national networks should encourage monitoring of reefs and associated habitats by volunteers and communities and provide them with the necessary training;
- Coral reef awareness programs should be expanded to reach a larger proportion of the population, especially by promoting Reef Check which uses low and medium-tech protocols for monitoring coral reef status;
- The new COREMO III database, a product originating from the SWIO region, should be adopted in the region for entering and archiving monitoring data and appropriate training should be offered to understand its potential use;
- The regional network should increase collaboration with other global or regional programs such as RECOMAP, RAMP and AMESD and the Global Invasive Species Program;
- Coral reef monitoring data from the region should be collated, analysed and published in peer-reviewed journals to improve visibility of the regional network, increase availability of scientific information to the scientific community and to improve scientific input into regional management programs;

- New sources of financing should be investigated to ensure sustainability of monitoring and management of coral reefs and associated habitats in the region.
  - These funds should preferably go through the Sustainable Seas Trust, an initiative of the countries of the Western Indian Ocean;
  - Funds obtained should be earmarked to support monitoring, research and awareness on coral reefs and associated habitats in the countries of the SWIO node;
  - Only profits from the funds should be used thus ensuring sustainability and continued management.

### AUTHOR CONTACTS

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### STATUS OF THE CORAL REEFS OF MAYOTTE – COMOROS ARCHIPELAGO

The 2 main islands and 30 volcanic and coral islets of Mayotte are part of the Comoros Archipelago. While the total land area is 376 km<sup>2</sup>, the much larger lagoon (1500 km<sup>2</sup>) is of critical social and economic importance for fisheries and tourism, as well as being a key location for maintaining marine biodiversity in the upper Mozambique Channel. Principal characteristics of the coral reefs are:

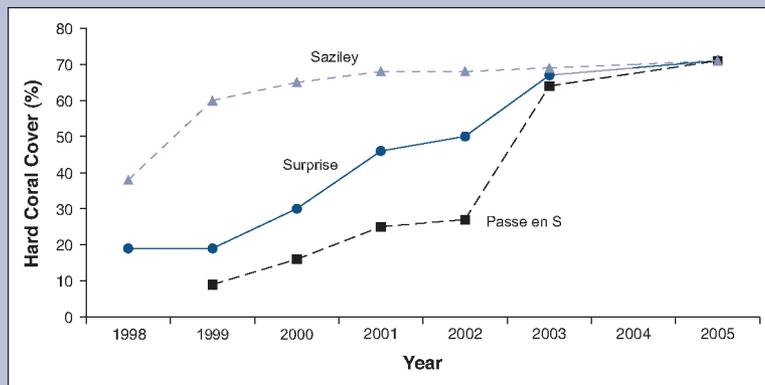
- the length of the barrier reefs defining one of the widest lagoons in the western Indian Ocean;
- a double reef-barrier (a rare geological structure); and
- high biodiversity and richness of associated habitats (mangroves, seagrass beds etc.).

The seagrass beds are particularly important for turtle and dugong populations, which are seriously threatened throughout the region. Such remarkable biodiversity is also illustrated by the high diversity of seagrasses (12 species), marine mammals (22) and hard or hermatypic corals (254 species in 65 genera). More than 2300 marine species have been recorded, but some groups remain poorly known. Mangroves are well developed (7.35 km<sup>2</sup>) and under protection following the acquisition of the coastline by the Conservatory. An atlas of mangroves has been completed, and there are projects on restoration and cleaning, but there are no permanent monitoring sites.

Monitoring coral reef status started in 1998 as part of the Coral Reefs Observatory (ORC), which conducts annual spatial and temporal evaluation of the bottom and fish populations, using GCRMN protocols adapted for the WIO region. More specific activities have been implemented (assessing coral bleaching, ciguatera etc.) to provide local decision makers with an efficient GIS-database for management and conservation. Besides annual monitoring, a 'vitality assessment' is undertaken every 7 years, which provides a diagnosis of the fringing reefs. There is also a volunteer Reef Check program, and both GCRMN and Reef Check data are stored and analysed using the CoReMo data entry system.

The major threats to coral reef health are both regional (e.g. severe bleaching and subsequent mortality in 1998 which affected more than 95% of Mayotte corals) and

local (over-fishing, and land-based pollution such as sewage, sediment, etc.). Many responses to environmental degradation have been implemented by the authorities since the 1980s, but the human population continues to grow rapidly, increasing pressures on the ecosystem which will require greater efforts to maintain the ecological and socioeconomic processes. ORC results in the graph below show that, despite existing and increasing pressures, there has been a positive and encouraging recovery on the fringing, inner and barrier reefs since the 1998 bleaching event. However coral cover on the fringing reefs since the first surveys in 1989 has decreased in proportion to human pressures. There is a project to designate the Mayotte Lagoon as a Natural Marine Park with significant local participatory involvement to ensure the sustainable use of the marine resources and conservation of endangered species and traditional habits (from Vincent Dinhut, Jean-Benoît Nicet, Jean-Pascal Quod, [jpascal.quod@arvam.com](mailto:jpascal.quod@arvam.com)).



***Hard coral cover at 3 m depth has shown a major increase after the losses in 1998 such that there is about 70% cover at the monitoring sites on the fringing (Surprise), inner (Passe en S) and barrier (Sazily) reefs.***

## 8. STATUS OF CORAL REEFS IN SOUTH ASIA: BANGLADESH, CHAGOS, INDIA, MALDIVES AND SRI LANKA

JERKER TAMELANDER AND ARJAN RAJASURIYA

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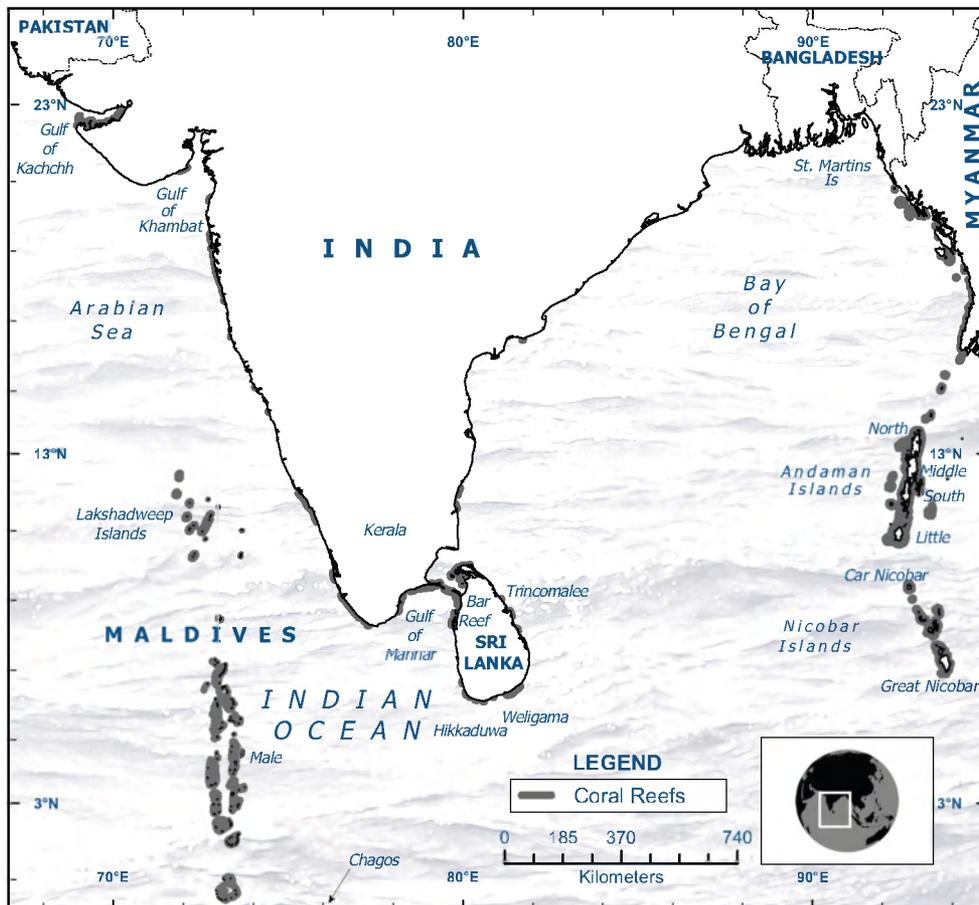
### ABSTRACT

- Recovery of South Asian coral reefs since the 1998 mass bleaching has been patchy; Chagos has shown particularly good recovery, reefs in the western atoll chain of the Maldives and Bar Reef in Sri Lanka have also recovered relatively well, while many reefs near Sri Lanka and reefs in the eastern atoll chain of the Maldives have shown little or no recovery;
- The 2004 Indian Ocean earthquake and tsunami caused significant reef damage at some sites (e.g. Andaman and Nicobar Islands), and reversed some recovery after 1998 (as in parts of Sri Lanka). The tsunami damage will not be long lasting, except for reefs uplifted out of the water, or buried under sediments;
- Direct human stresses are the main cause of reef degradation near dense human populations. This is being compounded by climate change stress;
- Stressed reefs have reduced resistance or resilience to climate stress and will provide fewer services and products for poor coastal communities with a high dependence on coral reefs;
- More efforts are required to assess ecological and socioeconomic status and trends to improve management effectiveness. Application of resilience principles in ecosystem and resource management is required to address the needs of coastal communities and conserve reef resources.

## INTRODUCTION

The South Asian countries with coral reefs or coral communities are Bangladesh, India, Maldives, Pakistan and Sri Lanka, as well as the United Kingdom overseas territory of Chagos (British Indian Ocean Territory, BIOT). The major coral reefs include atolls along the more than 2000 km Lakshadweep-Maldives-Chagos ridge; fringing and patch reefs in the Andaman and Nicobar Islands, India, around the Gulf of Mannar in India and Sri Lanka, and along the south western and eastern coastline of Sri Lanka. Less well developed coral communities occur in other parts of India, especially in the Gulf of Kachchh, as well as along the coast of Maharashtra, Goa, Karnataka, Kerala and Tamil Nadu. Limited and rather poorly studied coral communities are found around St. Martins Island/Jinjiradwip and Jinjira reefs in Bangladesh, and along the Baluchistan coast in Pakistan, including around Astola Island and Gwadar.

Coastal and marine ecosystems and resources provide large benefits to the countries of the region through fisheries and tourism, which are highly important economic sectors in the Maldives, India and Sri Lanka. Many people throughout the region are directly dependent on reef resources, however, poverty is widespread, especially among coastal populations (which are also dependent on other natural resources). Millions of people rely heavily on coastal and



marine ecosystems and resources for employment, income, and food protein. For example, in the Lakshadweep Islands as much as 90% of the protein intake for poor households comes from reef fishing and gleaning.

Climate change is the main regional threat to coral reefs in South Asia. Impacts from higher temperatures, more variable precipitation, more extreme weather events and sea level rise are already being felt in South Asia and will continue to intensify. A reduction in calcification rates caused by rising ocean acidification may be equally severe or even more so. However, reefs are also facing severe direct human stresses from over-fishing and destructive fishing, coastal development, runoff from land and increased sedimentation. These are the main drivers of reef degradation: areas where human impact and use of reef resources has been minimal are presently comparatively healthier (e.g. Chagos and around the Jaffna Peninsula in northern Sri Lanka) than other areas. Poor management of coastal areas, including many MPAs, as well as intensive reef resource use, remains a concern in all countries.

#### **STATUS OF REEFS UNTIL 2004**

Coral reefs in South Asia suffered large-scale bleaching in 1998 with a catastrophic reduction in coral cover. The impact was variable, with up to 90% mortality in many areas, including most reefs along the Lakhadweep-Maldives-Chagos ridge (these make up more than three quarters of the region's reefs), as well as most reefs in Sri Lanka. Other areas showed much lower bleaching mortality, such as the Indian coast of the Gulf of Mannar, and the Andaman and Nicobar Islands. Unfortunately, there were no baseline data on the coral and reef fish communities in large parts of the region to determine the full extent of the 1998 bleaching damage. Coral bleaching has been observed almost yearly in the region since 1998, but mostly at a local scale and during the warm and calm period in April-May. There has been some localized mortality, but usually the reefs recover fully within a few months. A more detailed description of reef status and damage from region-wide events can be found in GCRMN status reports in 1998, 2000, 2002, 2004, 2006 and the CORDIO reports from 1999, 2000, 2002, 2005 and 2008 (listed in Suggested Reading on the accompanying CD).

#### **STATUS OF CORAL REEFS: 2008**

No clear and consistent regional trend in coral reef status in South Asia can be identified; although some broad patterns can be distinguished. These include an overall increase in coral cover in recent years but these gains are often threatened by continued human stresses. The tsunami had a much lower impact on coral reefs than the bleaching in 1998, and much lower than the chronic human stresses.

**Chagos (BIOT):** The last surveys in 2006 show strong recovery of coral cover after the mass mortality in 1998 in the Chagos archipelago. There were significant differences in reef bottom composition between atolls and different depths, as well as between sites in the same atoll. However, living corals and other animals far exceeded non-living substrate at all sites and depths, except for Egmont Atoll. Hard coral cover was the most prominent form of living benthos, and coral cover exceeded 70% on several reefs. Lagoon patch reefs showed generally higher coral cover at 25 m depth than did outer reef slopes. Coral larval recruitment was very strong, such that the lowest Chagos recruit densities were at least 10 times higher than rates of recruitment at most other reefs in the central and western Indian Ocean.

There have probably been several minor shallow-water bleaching events in Chagos in the past few years, including a substantial, but localised, coral mortality at Egmont Atoll where more than 95% of the corals died in 2005. Overall, the archipelago-wide recovery of Chagos reefs far exceeded recovery anywhere else in the Indian Ocean and the very low level of direct human stresses on these reefs is a partial explanation. Chagos, therefore, probably plays a critical biogeographical and reservoir role for reefs in the central and western Indian Ocean.

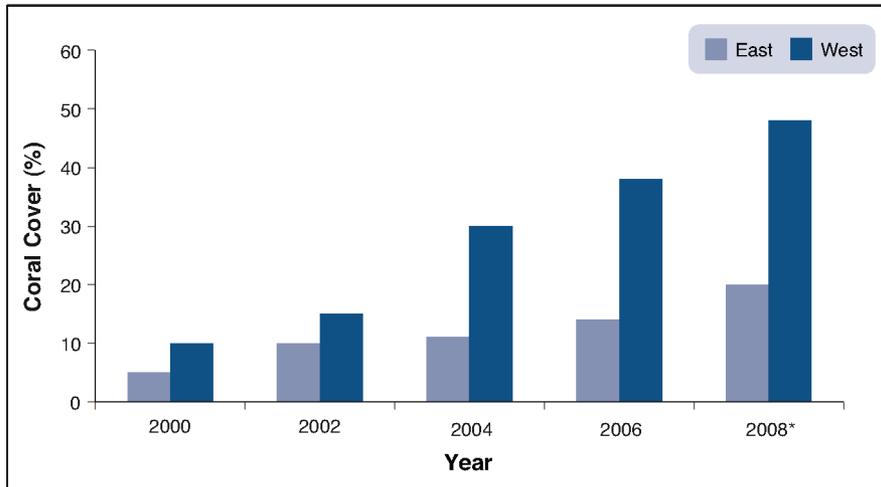
**The Maldives:** Coral cover is increasing at all sites across most atolls in the Maldives that were surveyed between 2006 and 2008; but reef recovery is highly variable. Live coral cover ranges from less than 10% to more than 80%, with much higher coral cover generally found on western atolls than those along the eastern chain. There is also some variation within atolls. The differences are probably due to site-specific factors such as current, weather conditions and the number of available larvae. The *Acropora* species that were virtually wiped out during the 1998 bleaching, now dominate the coral community at most lagoon sites. This is the dominant genus where there have been large increases in coral cover, and large table corals more than 1 m in diameter are common. The Agariciidae and Poritidae are still abundant at most sites and dominant on many outer slopes. While coral cover is now at the same level as in the pre-1998 community at many sites, the coral size class distribution still reflects the fact that the reefs are recovering, with the majority of colonies between 10 and 20 cm in diameter, followed by 20-40 cm sizes. Coral diseases, such as white band and black band, are less frequent than previously observed at some reef sites, while the sponge *Terpios hoshinota* is common at some sites where it overgrows and kills several coral species.

A bleaching surveillance program called 'Bleach-watch Maldives' was initiated by the Marine Research Centre and the Ministry of Tourism in mid March 2007 to involve dive schools as a network of voluntary observers. Some evidence of temperature stress was observed between March and May 2007 but there was no significant or large scale bleaching.

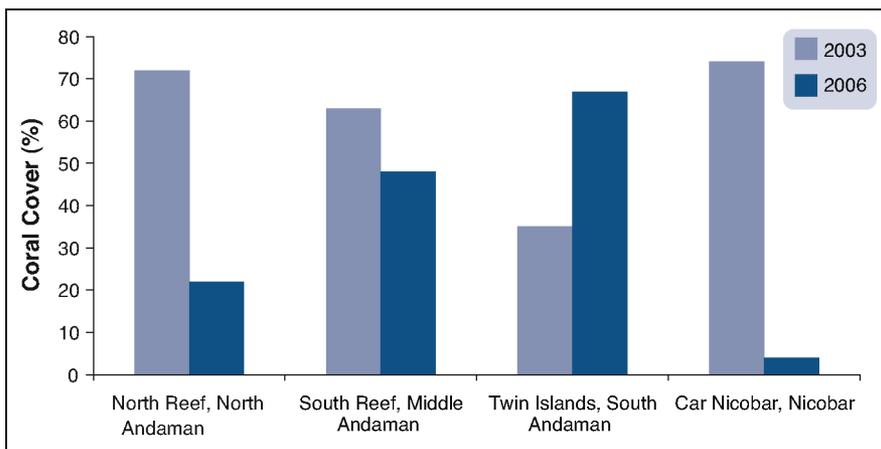
**India:** Detailed information is reported on the main Indian reef areas, including the Lakshadweep Islands, Andaman and Nicobar Islands, and Gulf of Mannar, with limited and largely anecdotal information for reefs elsewhere in the country. The patterns of reef recovery described previously are continuing in the Lakshadweep islands with coral cover increasing at most reef sites. Recovery is faster on west-facing than eastern sites, largely due to differences in settlement patterns and substrate stability. There has been a reduction in algal turf and macro-algal cover compared to earlier studies, possibly explained by healthy populations of algal eating fish, particularly scarids and acanthurids, which are reported to facilitate coral recovery. The former dominant *Acropora* species, such as *A. abrotanoides*, are returning to dominance. An increase in coral bleaching at levels higher than normal summer bleaching was observed in April 2007; the extent and mortality is not known but appears to be limited.

The impact of the 2004 tsunami was examined in detail on the Andaman and Nicobar Islands in 2005 and 2006. More than 100 km<sup>2</sup> of shallow reef area was damaged in the Andaman Islands with most of this due to tectonic uplift and aerial exposure, as well as by the tsunami waves carving channels between islands. Many reef areas, especially in the Andaman Islands, were moderately to slightly affected and coral cover remains between 30 and 70%. A significant reduction in coral cover occurred at North Reef, Northern Andaman, and Interview Island, Middle Andaman. More than 200 km<sup>2</sup> of reef was damaged in the Nicobar Islands due to tectonic activity, the

tsunami and consequent sedimentation. Subsidence of the islands changed beach profiles and high erosion and sedimentation continued for more than 8 months after the tsunami. Severe damage in these areas extended to more than 20 m depth. Coral cover at Car Nicobar is now about 5% after suffering more than 90% mortality. Good coral larval recruitment has been reported from the Andaman Islands, while in the Nicobars it remains negligible. In some parts of the Nicobar Islands hard corals are facing competition from soft corals.

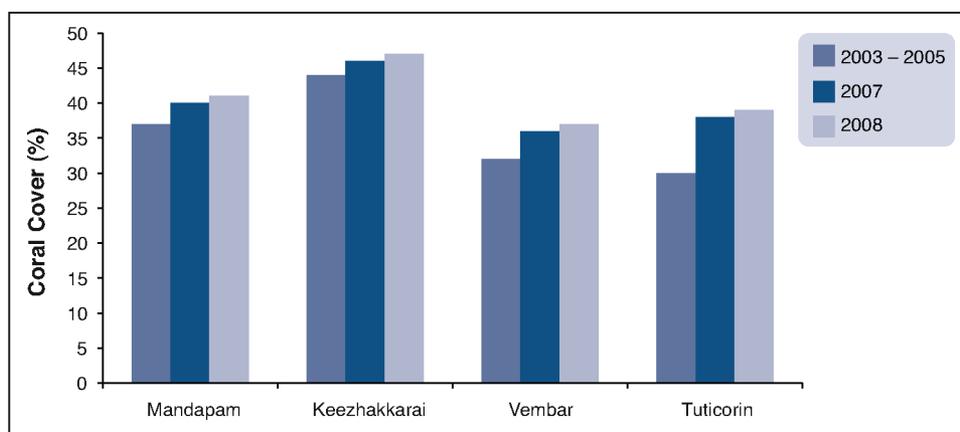


*Coral cover on eastward and westward facing reefs in the Lakshadweep Islands, India, continues the recovery that was reported in 2004. The differences between East and West appears to be due to substrate stability and new coral settlement patterns (\* estimate; from Rohan Arthur/NCF and CORDIO reports).*



*This graph shows the highly variable pattern of coral cover in the Andaman and Nicobar Islands between 2003 and 2006. The losses due to the December 2004 earthquake and tsunami are clearly seen at 3 monitoring sites.*

Average live coral cover around the 21 islands in the Gulf of Mannar is 35%, a slight increase over the past 5 years. The highest coral cover occurs in the Keezhakkarai island group (44%) and the lowest in the Tuticorin Group (29%): 117 coral species were recorded in the area in 2005, including 13 new records. Habitat structures, in particular live corals, play a major role in enhancing fish diversity and 50 reef-associated fish species in 27 families were observed in 2005. The Gulf of Mannar coral reefs are under considerable stress due to the proximity of the mainland and high coastal populations, urban centres and land-based activities. Sedimentation from numerous sources is high, including monsoonal runoff, sewage disposal, industrial discharge and coastal development, and the destructive fishing methods used in the area cause considerable re-suspension of sediment. Sediment loads appear to have increased over the last 10 years. However, some progress has been made with the cessation of illegal coral mining activities.

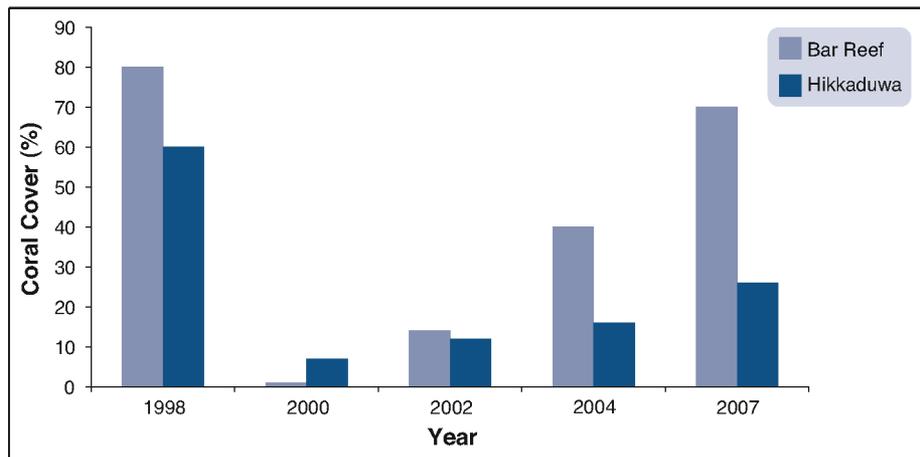


***Coral cover in the 4 main island groups of the Gulf of Mannar, India, is gradually increasing after some losses in 1998. Mortality from almost annual bleaching events is usually negligible (from JK Patterson Edward/SDMRI and reports by CORDIO and GCRMN).***

The state of Gujarat has a 1650 km long coastline with a broad continental shelf: it contains 35% of India's total shelf area, including 7350 km<sup>2</sup> of the shallow Gulf of Kachchh. The marine environment in the Gulf of Kachchh is extreme, with water temperatures varying between 15° and 30°C and high salinity in areas with high evaporation. The tidal range is very high and the waters are particularly turbid which limits coral reef development. Coral communities (total area, 460 km<sup>2</sup>) are found around 20 of the 42 islands, 20 islands have mangroves, while 6 'islands' are submerged. Industrial development is intense in the Gulf, with 11 ports and 21 major salt industry sites producing >70% of India's total salt production.

**Sri Lanka:** The highest rate of recovery from the mass bleaching in 1998 has been recorded at Bar Reef Marine Sanctuary where coral cover increased from 40% in 2004 to about 70% in early 2007, largely due to rapid growth of *Acropora cytherea* and *Pocillopora damicornis*. There has been a high level of recruitment and growth of *P. damicornis* on most reefs including those in the south. Coral cover at Hikkaduwa has increased from 12% in 2005 to 26% in 2007. However, there has been slower reef recovery in other parts of the south-west; and some areas show a slight decrease, largely due to direct human stress compounded by the tsunami. An increase in the growth of the calcareous alga *Halimeda* and high levels of sedimentation has

damaged some fringing reefs, especially in the south, with algal cover increasing from 10% in 2005 to 60% in 2006 at Kapparatota. The comparatively lower stress on reefs in previously unsurveyed areas of northern Sri Lanka seem to have kept these reefs relatively undamaged, and reefs around the Jaffna Peninsula in 2005 exhibited live hard coral cover of 45% dominated by massive corals. Many reefs in Sri Lanka lack effective management with many illegal activities, such as live coral mining and fishing using unsustainable gear and dynamite. MPAs remain poorly managed and compliance with regulations is low with the possible exception of Hikkaduwa. The escalation of internal conflict in the country prevents active work in the northern and eastern parts of the country.



*These graphs clearly show the dramatic effects of the 1998 coral bleaching on reefs in Sri Lanka, in this case Bar Reef and Hikkaduwa marine parks. The coral cover recovery from the 1998 losses is highly variable, with much higher human stress levels at Hikkaduwa (from Arjan Rajasuriya/NARA and reports by CORDIO and GCRMN).*

**Bangladesh:** The coral communities around St. Martins Island were surveyed between 2005 and 2007. The area is highly turbid during most of the year and the substrate is mostly unstable which has limited coral growth. Large rocks provide suitable substrate for coral settlement and moderate recruitment of juvenile corals has been observed. However, the boulders are subject to frequent overturning by storm surges. Live coral cover is low around the island, generally around 5%, although somewhat higher (10–15%) in the north-west rocky shoal, Boro Shiler Bandh. *Porites* dominates the hard coral community, followed by *Favites*, *Goniopora*, *Cyphastrea* and *Goniastrea*: there are 66 species of scleractinian corals in 22 genera and 15 families. Only limited coral bleaching has been observed since 1998. The area was declared an Ecologically Critical Area in 1999 under the Bangladesh Environmental Conservation Act.

**Pakistan:** The coral communities along the Baluchistan coast have been poorly studied, although surveys around Jiwani and the area near Astola Island identified 25 coral species and 77 reef fish species. National capacity to survey and monitor coral reefs remains weak, while mangrove and coastal wetland management initiatives are better developed.

## **SOCIOECONOMIC MONITORING**

A South Asia regional GCRMN SocMon Node was established at IUCN through the Coral Reefs and Livelihoods Initiative (CORALI, [www.coralweb.org](http://www.coralweb.org)), a collaborative initiative involving IUCN, CORDIO, ICRAN, SACEP and IMM Ltd as well as national institutions, NGOs and CBOs (community based organisations). Regionally appropriate methods for socioeconomic monitoring have been developed and tested through CORALI pilot site initiatives in 6 locations around the region, and a regional SocMon manual has been prepared by IUCN and CARESS. CORALI has adopted a people-centred and poverty-focused approach to working with people who depend on coral reef resources for a key part of their livelihoods. An action research process has been designed to take lessons from past experiences (global and regional) and use the local knowledge and field-experiences of partners in the region to further develop and field-test a Sustainable Livelihoods Enhancement and Diversification (SLED) approach.

## **STATUS OF MANGROVES, SEAGRASSES AND FISHERIES**

The 6000 km<sup>2</sup> Sundarbans between Bangladesh and India is the largest mangrove area in the world. Other major mangrove areas in South Asia include the Indus delta of Pakistan, the sixth largest mangrove area in the world, the Gulf of Kachchh in India, and the Puttalam, Trincomalee and Batticaloa areas of Sri Lanka. There is very little mangrove growth in the Lakshadweeps, Maldives and Chagos. Surveys of mangroves in and around the Gulf of Kachchh identified 13 true mangrove species, 3 of which are abundant; but 4 have not been seen for more than 20 years. Presently Gujarat is the only Indian state where mangrove cover is increasing. This is due in part to a large reforestation program, however, the need for land for industrial development and human settlement remains a major threat.

Mangroves throughout the region are threatened by industrial development, conversion to aquaculture, wood cutting and, in some cases, siltation or erosion; and many mangrove areas are declining. The Indian Ocean tsunami in 2004 also caused widespread mangrove losses and, in response, the Mangroves for the Future (MFF) initiative was launched. MFF is a broad partnership of governments, international agencies and civil society focusing on the countries worst-affected by the tsunami — India, Indonesia, Maldives, Seychelles, Sri Lanka, and Thailand, however, it also includes other countries facing similar issues. Using mangroves as a flagship ecosystem, the overall aim of MFF is to promote an integrated ocean-wide approach to coastal zone management by influencing regional cooperation through national program support, private sector engagement and community action. A comprehensive strategy has been prepared.

Fisheries continue to provide much of the income and protein food for coastal populations in South Asia. However, there are significant concerns about the sustainability of both industrial and artisanal fishing and it is clear several resources are over-harvested. This includes the sea cucumber fishery in Sri Lanka, where sea cucumbers are now rare at depths less than 30 m due to intense collection. There are also downward trends in catches of many fin fish across the region, and ornamental fish collection using destructive methods continues in Sri Lanka and India. Fishing pressure is also increasing on some resources previously comparatively less exploited. This includes an increasing grouper fishery in the Lakshadweep islands and the Maldives driven by the high export value of these reef fish. It is feared the growth in the fishery will result in severe over-harvesting, as seen throughout the world, faster than management

interventions can be implemented. A regional interview survey of fish spawning aggregations, by IUCN and CORDIO in collaboration with national organizations, in 2006 and 2007 found little indigenous knowledge of spawning aggregations. Several potential reef fish spawning aggregation sites were identified but the results cannot be verified and thus are indicative only. The Maldives is the only country where several confirmed reef fish spawning aggregation sites have been identified but spawning aggregations of *Epinephelus fuscoguttatus*, *Plectropomus areolatus* and *P. pessuliferus* are targeted by fishermen. Reef fish spawning aggregations have not been considered in fisheries management policy settings largely due to a low level of knowledge. This poses a potential threat to fish species involved in spawning aggregations.

## CONCLUSIONS

There has been a positive trend in reef status across South Asia since 2004 if coral cover is used as the sole indicator. However, the region is still struggling to recover from the massive impact of bleaching in 1998 and the smaller impacts of the Indian Ocean Tsunami of 2004. It is clear that the rate of recovery, with some notable exceptions, is mostly moderate or slow, largely due to direct human stresses. Similarly, many reefs in the region have changed considerably from their original state in terms of species composition and ecological functionality.

There are also no significant regional changes in the number and magnitude of threats to coral reefs, mangroves and seagrass beds in South Asia. In many areas localised stress is becoming increasingly severe, especially around urban centres and highly populated areas, from over-fishing and pollution from the land. This compounds climate change impacts, which are already being experienced and are very likely to become more severe in the next 10 years. In parallel, however, environmental and resource management initiatives are increasing throughout the region, involving governments as well as NGOs and CBOs. There are also several positive examples of damage reduction, including the cessation of live coral mining in the Gulf of Mannar, India (though coral mining remains rampant in Sri Lanka).

There is also a positive trend in coral reef monitoring and research in the region with an increasing number of skilled professionals emerging from tertiary training and other capacity building initiatives. Improved monitoring and research is on-going, with increased geographic coverage. Although there are some notable exceptions, marine and fisheries management remain poor due to capacity and funding constraints, difficulty in harmonizing needs of many diverse stakeholders and a lack of political will. As a consequence, many MPAs in the region remain paper parks with little active management and widespread breaches of regulations.

## RECOMMENDATIONS

These recommendations follow from assessments of progress and status in reef research, monitoring and management. Most recommendations apply across the entire region, however some are more country-specific. The examples do not constitute an exhaustive list, but rather serve to illustrate the recommended focus of actions and responses.

- There is a continued need to strengthen coral reef monitoring and research in South Asia to reinforce positive recovery trends and rectify particular gaps. Capacity needs strengthening where data are scarce, such as Bangladesh and Pakistan, as well as improving coverage of the vast reef areas of the Maldives and India. There is also a need for sound data management, analysis and reporting. Frequently data generation

is sub-optimal, not analysed well or not published or reported. Broader application of more comprehensive coral reef monitoring approaches, such as the Resilience Assessment methodology developed by the IUCN Climate Change and Coral Reefs Working Group, should be encouraged.

- There is a particular need to control more destructive and unsustainable practices. Many of these are currently illegal, including coral mining and dynamite fishing in Sri Lanka. Similarly, harvesting of under sized crustaceans in the Gulf of Mannar, India and Sri Lanka is threatening a valuable resource and needs to be controlled.
- Management of MPAs should be strengthened; some recent regional and national initiatives have addressed this but are insufficient and most areas continue to be poorly managed. There is insufficient capacity to manage MPAs and management effectiveness has not been reviewed in order to improve management decision making and strategies.
- There is a need to address emerging issues, such as new or evolving resource use. This includes a precautionary approach to increased exploitation of grouper stocks in the Lakshadweep islands and the Maldives which should be linked to information on fish reproductive behaviour. The ornamental fish trade is a high-value industry in Sri Lanka and the Maldives and growing in India; regulation monitoring and enforcement of collection are required, based on valid resource status data. Careful management could prevent these from collapsing like many other reef resources in the region.
- The increasing synergistic effects of climate change and other stresses require particular attention including research as well as monitoring and management responses. The enhanced use of research and monitoring results in management policy formulation is recommended, such as using the framework of reef resilience principles.
- More genuine and inclusive collaborative approaches in resource management are required. Increased collaboration between government, NGOs and CBOs and, in particular, the empowerment of communities to participate meaningfully is necessary. It is recognized that multiplicity and pluralism strengthens science as well as management; similarly, partnerships with the private sector can strengthen environmental and resource management. Good examples exist at some resort islands in the Maldives. However, a fundamental need is that governments, in collaboration with NGOs, provide both the oversight and guidance to the private sector to fulfil their potential as sustainable resource managers.

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Numerous institutions, projects and individuals from around the region have provided key information and syntheses; without their dedicated work it would not have been possible to compile this report. We particularly acknowledge the important role of CORDIO and IUCN in supporting and coordinating reef monitoring and related activities. Their collaboration with ICRAN, IMM Ltd and SACEP and national partners has also led to the establishment of the South Asia regional SocMon node.

## AUTHOR CONTACTS

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- Cattermoul B. Sriskanthan, Campbell. The Coral Reefs and Livelihoods Initiative (CORALI) - Building an improved approach to livelihood enhancement and diversification with coral reef users in South Asia and the Andaman Sea;
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## EFFECTS OF THE 2004 INDIAN OCEAN TSUNAMI ON CORAL REEFS

More than 230 000 people died during the Great Sumatra-Andaman Megathrust Earthquake that started near Simileu Island, Sumatra on 26 December 2004. The 9.15–9.3 magnitude earthquake lasted 8½ minutes as the pressure between the Indian and Asian tectonic plates released suddenly along the 1300 kilometre subduction fault. The earthquake forced the deep ocean floor up or down by 10 m and moved massive volumes of seawater to form the disastrous tsunamis. These waves caused massive damage on the land, but caused much less damage to the coral reefs; most should recover in 5 to 10 years. Most reef damage was caused by debris and sediments washed off the land, rather than from destructive waves. Some coral reefs were destroyed when they were lifted out of the water during the earthquake. This was particularly evident in northwest Sumatra and in the Andaman Islands of India.

Losses were greatest in Sumatra, Indonesia where 170 000 people died, 70% of the fishing fleet was lost, aquaculture was virtually destroyed, and about 30% of the coral reefs were severely damaged with major economic loss. Similarly, about 600 hectares of seagrasses and 85 000 hectares of mangroves were lost. There was minimal damage in Malaysia, although lives were lost. However, Thailand received the full force of the tsunami, resulting in more than 8000 deaths and major damage to tourism and fishing infrastructure. About 13% of the reefs were severely damaged, a further 9% were moderately damaged, whereas 61% were virtually undamaged. The broken or overturned corals are now showing rapid recovery. There was minimal damage to reefs in Myanmar. However, in the Andaman and Nicobar Islands of India, many shallow reefs to the west were uplifted, whereas reefs in the east were buried under sediments from land erosion. The broken corals have largely recovered and some sediment damaged reefs are also recovering. Reefs on the mainland of India were largely unaffected, however large areas of mangroves and coastal forests were damaged, although they protected people and the land from major wave damage. The east and south coasts of Sri Lanka were damaged by waves which killed 31 000 people. Reef damage was patchy with most losses due to dead coral rubble being thrown around by the waves. Much of this rubble resulted from the 1998 coral bleaching or from unsustainable fishing and pollution. Surges of water flowed over the Maldives causing about 100 deaths and major losses to infrastructure and the tourism industry. The tsunami was less damaging to corals than that previously due to illegal harvesting of coral rock and sand for building. Reefs in the Seychelles, East Africa and Yemen were not markedly affected, although there was loss of life in Somalia.

The 2006 GCRMN report on the tsunami and coral reefs concluded that human activities caused more damage to Indian Ocean coral reefs through over-fishing, unsustainable land use and deforestation, and climate change. An early warning system was clearly required to protect the coastal peoples of the Indian Ocean, as well as an effective coral reef monitoring programme as many countries could not assess tsunami damage due to a lack of baseline data (from Wilkinson C, Souter D, Goldberg J (2006). *Status of Coral Reefs in Tsunami Affected Countries: 2005. Australian Institute of Marine Science and Global Coral Reef Monitoring Network, Townsville Australia, 154 p.*).

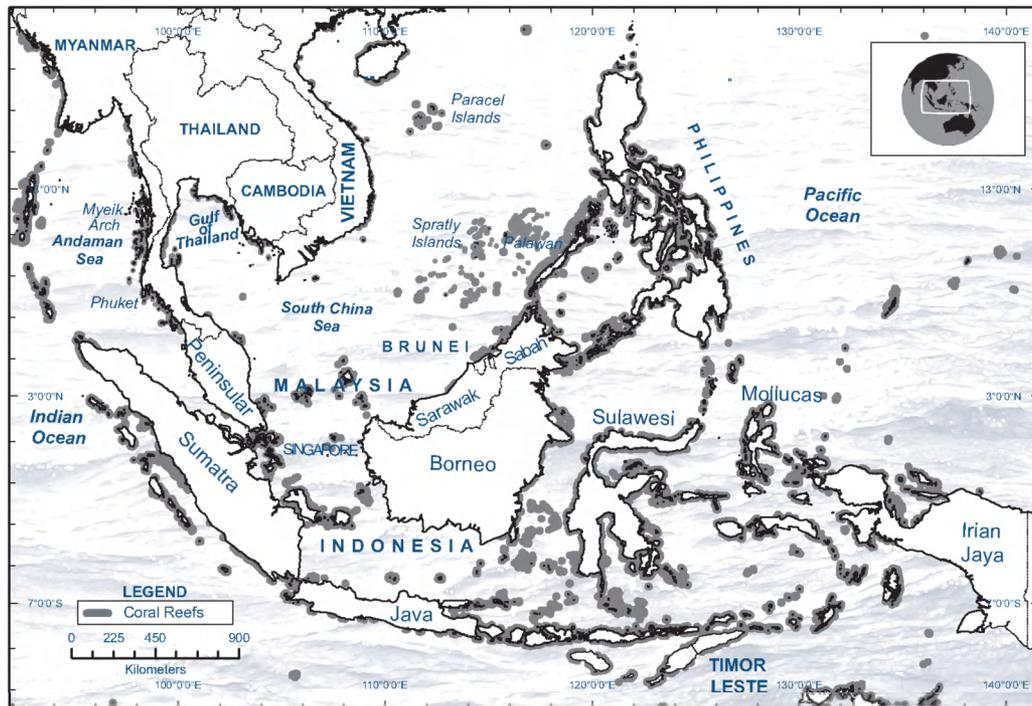
## 9. STATUS OF CORAL REEFS IN SOUTHEAST ASIA

KARENNE TUN, CHOU LOKE MING, THAMASAK YEEMIN,  
NIPHON PHONGSUWAN, AFFENDI YANG AMRI, NIÑA HO, KIM SOUR,  
NGUYEN VAN LONG, CLETO NANOLA, DAVID LANE, YOSEPHINE TUTI

### ABSTRACT

- Between 2004 and 2008, the condition of coral reefs improved in Thailand, Philippines, Vietnam and Singapore but declined in Indonesia and Malaysia (however, many reefs were not assessed);
- Coral reef status in Cambodia, Myanmar and Timor-Leste (p. 176) is largely unknown, there is no new information from Brunei, but little change is expected;
- Timor-Leste is included for the first time as the tenth Southeast Asian coral reef country;
- Coral reef area estimates of just under 100 000 km<sup>2</sup> for the region are probably a gross overestimate; recent GIS analysis in Thailand and Singapore shows reef area is approximately 10 times lower, possibly because non-reef sea areas were previously included;
- The 2004 Indian Ocean tsunami caused localized coral reef damage in Indonesia, Thailand and Malaysia. Post-tsunami assessments indicate there was severe localised damage in a few areas, and minimal damage on most reefs. Recovery from the tsunami is expected to take 5–10 years for most affected reefs, and 20 years for severely damaged reefs;
- Fish stocks in the Gulf of Thailand and South China Sea assessed under the UNEP/GEF South China Sea Project indicate that most stocks are under high fishing effort, with most target species considered fully fished or over-fished;
- Losses of seagrass habitats are estimated at 30 – 60% in Indonesia, Philippines, Thailand and Singapore; but largely un-assessed in other SEA countries;
- More than 50% of the region's mangroves have been lost, with 10% of the losses occurring between 1993 and 2003;

- Socioeconomic assessment has expanded greatly since 2004 in Southeast Asian countries, particularly Indonesia and the Philippines;
- An assessment of MPAs of East Asia in 2005–2007 showed the number of MPAs with coral reefs increased from 178 in 2003 to 403 in 2007;
- Large-scale, multi-agency projects have increased, including: The Coral Triangle Initiative; UNEP/GEF South China Sea Project; WWF Sulu-Sulawesi Marine Ecoregion Programme; GEF Coral Reef Targeted Research for Capacity Building and Management; EU project on Developing Ubiquitous Practices for Restoration of Indo-Pacific Reefs and Green Fins Programme;
- Coral reef management has improved in most countries, but is still lacking in Cambodia, Myanmar and Timor Leste;
- The first Asia Pacific Coral Reef Symposium in Hong Kong in June 2006 was spearheaded by the GCRMN Nodes of East Asia and Southeast Asia; the second symposium is scheduled for Phuket, Thailand in 2010;
- A region-specific meta-database and summary programme is needed to be integrated into the ReefBase platform for better data awareness and management.



## INTRODUCTION

South-east Asia (SEA) contains the largest area of coral reefs with 34% of world's total; the region is regarded as the global centre of tropical marine biodiversity, with 600 hard coral species and more than 1300 reef-associated fish species. 'Hot spots' of hard coral diversity are widely distributed within the region, with many sites containing more than 200 coral species. Most reefs within SEA are on the continental Sunda and Sahul Shelves, with all reef types found here – fringing, platform, barrier reefs and atolls.

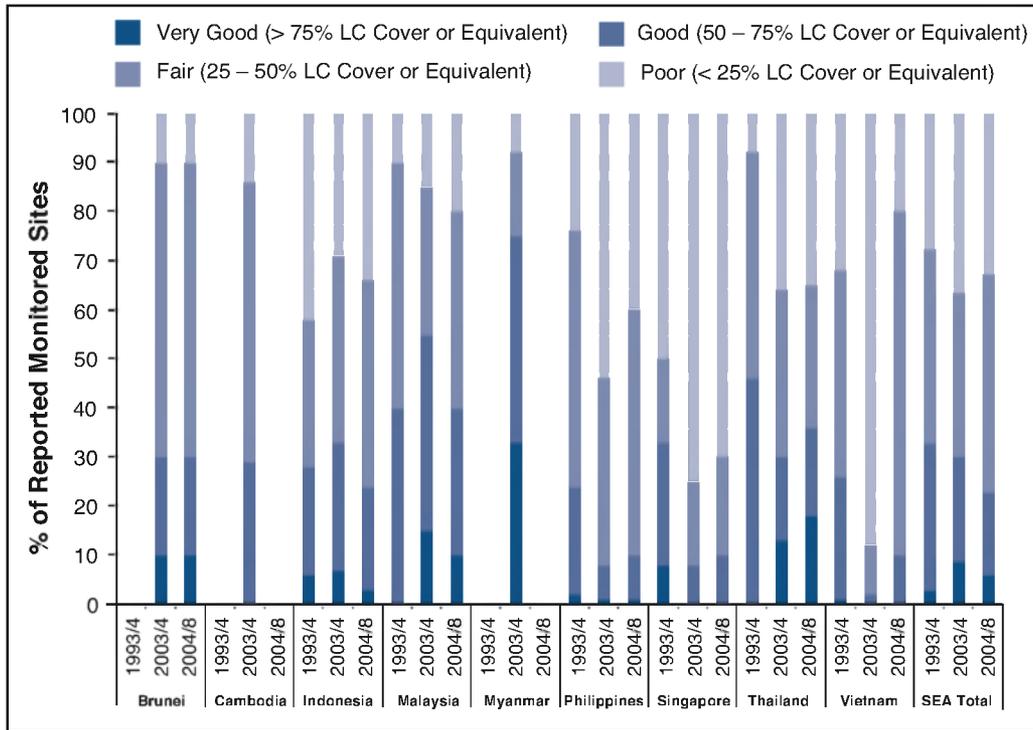
More than 60% of the 557 million people of SEA (Population Reference Bureau, [www.prb.org/](http://www.prb.org/)) live within 60 km of the coast and many of these are intrinsically linked to the resources of the coast, especially coral reefs. Although many cities in SEA are developing and growing rapidly, most people of Indonesia, Philippines, Thailand, Vietnam and Cambodia remain highly dependent on coastal resources for their livelihoods, especially through fisheries. In 2002 an assessment of the potential economic value of well managed coral reefs in SEA was US\$12.7 billion, representing more than 40% of the estimated global value. With current global financial instability characterized by increasing inflation and a depreciating US dollar, the estimated potential economic value is expected to be higher.

The global 'Reefs at Risk' (R@R; [www.reefsatrisk.wri.org](http://www.reefsatrisk.wri.org)) assessment in 2002 'red-flagged' SEA coral reefs as the most threatened in the world and identified over-fishing and destructive fishing as the main threats, along with sedimentation and pollution, facing the reefs, with coastal development fast becoming a major threat in many coastal areas. The 'Status of Coral Reefs of the World: 2004' report echoed this sentiment of continual reef decline; but it also highlighted increasing awareness and management initiatives within the region.

## STATUS OF CORAL REEFS IN 2008

The biodiversity value of SEA coral reefs is unparalleled in the world with more coral and fish species than anywhere else including a high proportion of endemic species of corals, fishes, echinoderms and other reef species. Over the last 30 years there has been rapid population growth across the region resulting in a corresponding increase in coastal resource exploitation. Over-fishing and unsustainable fishing practices have led to declining fish stocks in almost all SEA countries, pushing many fishers to resort to destructive fishing practices like bomb and cyanide fishing to obtain food and fish to sell. This is especially evident in Indonesia, Philippines, Thailand, East Malaysia (Sabah) and Vietnam. An unfortunate outcome from this coastal fisheries dilemma is damage or destruction to coastal habitats like mangroves, seagrass beds and coral reefs. While efforts to restore or rehabilitate damaged or destroyed mangroves and seagrass beds have seen encouraging success, recovery of coral reefs has been far less successful.

Coral reef monitoring between 2004 and 2008 indicate that reefs continue to show an overall decline in condition in Indonesia and Malaysia, while there have been slight improvements in the overall reef condition in Philippines, Singapore and Thailand. The greatest improvement in reef condition however, was in Vietnam where most reefs in the 'poor' category shifted to the 'fair' category. This may not be a true reflection of the status as data for 2005–2006 were based on data summaries of 10 areas extracted from the UNEP/South China Sea Project GIS database and may not match the sites reported in previous status reports. Although updated coral status information was not available for Brunei, the reef conditions are expected to have remained unchanged, thus reflecting the same estimates reported in 2004.



***This graph shows the changes in live coral cover (as %) at reported monitoring sites in the Southeast Asian region between 1994 and 2008. There has been a general decline in those reefs previously with ‘Very Good’ and ‘Good’ coral cover, with a parallel increase in reefs with ‘Fair’ cover.***

The status of coral reefs in Cambodia, Myanmar and Timor-Leste (p. 176) remains largely unknown. There were status summaries in 2004 for Myanmar and Cambodia; but no verification or ‘guesstimates’ can be provided for this 2008 report. Assessments in 2004 and 2006 of the coral reefs in Timor-Leste around Atauro Island are summarized in the Box p. 176. These gaps for Myanmar, Cambodia and Timor-Leste emphasise the need for improved monitoring in the future.

The deadly Indian Ocean Tsunami of 26 December 2004 caused massive death and destruction on land but did not cause similar damage underwater. Post-tsunami assessments between 2005 and 2006 showed that the earthquake and resulting tsunamis damaged exposed areas in Indonesia, Thailand and Malaysia, with damage to coral reefs reported to be severe but localised in a few areas and minimal in most areas. Recovery from tsunami reef damage is expected within 5–10 years for most affected reefs, and up to 20 years for more severely damaged reefs. These results of post-tsunami country assessments were published in a 2006 GCRMN publication, ‘*Status of Coral Reefs in Tsunami Affected Countries: 2005*’.

The current published estimates of coral reef area for SEA is about 100 000 km<sup>2</sup> (R@R in Southeast Asia, 2002; MPAs of Southeast Asia, 2002). Recent GIS assessments by Thailand

and Singapore indicate that actual coral reef areas are about 10 times less, probably because the published estimates include sea areas surrounding the coral reefs in the assessment; the lagoons and not just the coral growth areas. Presumably, estimates for the other countries are similarly overestimated. A regional assessment to determine actual coral reef area will provide crucial information to determine coral reef status in the region. For example, threats to coral reefs may be more significant if actual estimates of coral reef area are lower than the reported estimates of 100 000 km<sup>2</sup> for the region.

Estimation of the proportion of reefs lost, and those under immediate and longer-term threat of loss should be based on a valid assessment matrix, similar to that developed for the R@R assessments. The current loss estimates are opinions of national experts based on their experience and local knowledge. These estimates are a mix of quantitative and qualitative assessment and increase confidence that they reflect the status of reefs in the region.

#### GREEN FINS – A NEW PROGRAMME FOR CORAL REEF CONSERVATION

*'To protect and conserve coral reefs by establishing and implementing environmentally friendly guidelines to promote a sustainable diving tourism industry':* that is the mission of the Green Fins Programme, initiated in 2004 by the UNEP Coordinating Body for the Seas of East Asia (COBSEA) to address the impacts of the diving and snorkelling industry on the coral reef habitats. The programme now operates in the Philippines, Thailand, Indonesia and Malaysia; all countries with large diving and snorkelling tourist industries. The unique angle of Green Fins is that it targets the environmental practices of dive operators and organisers of snorkelling groups by promoting environmentally friendly guidelines for divers. By involving dive operators as partners in the sustainable use of coral reefs, they also hope to raise the environmental awareness of the diving community. This is achieved through capacity building, training, certification programmes and the distribution of educational material:

- They have published a 'Code of Conduct' for 15 critical issues affecting reefs, including water quality, garbage/food waste management, mooring buoys, and boat discharges;
- Green Fins operators sign a pledge to manage and improve environmental practices and agree to be assessed and involve their staff and guests in on-going reef projects, such as the Reef-World ADOPT-A-REEF project with regular reef monitoring; and
- In Thailand, the Green Fins teams use the Reef Watch monitoring method, which is a one-dive-one-survey method for commercial operators and their guests (see data on [www.greenfins-thailand.org](http://www.greenfins-thailand.org)).

More information on Green Fins can be found on [www.greenfinsphilippines.com](http://www.greenfinsphilippines.com) or [www.greenfins.net](http://www.greenfins.net).

|  | BN               | KH             | ID               | MY               | MM           | PH               | SG               | TH               | TP                   | VN               |
|--|------------------|----------------|------------------|------------------|--------------|------------------|------------------|------------------|----------------------|------------------|
| <b>General Reef Demographic Statistics</b>   |                  |                |                  |                  |              |                  |                  |                  |                      |                  |
| Reef area (km <sup>2</sup> ) - Global Est.   | 187              | 150            | 50<br>875        | 4006             | 1686         | 25 819           | 50               | 2,130            | Currently<br>Unknown | 1122             |
| Reef area (km <sup>2</sup> ) - Country<br>Est.   | 187              | 284*           | 50<br>875        | 4006             | 1686         | 25 819           | <5↓*             | 1504*            | Currently<br>Unknown | 1122             |
| Est. % Reefs lost (cf. reefs<br>100 yrs ago)   | -                | -              | -                | -                | -            | -                | 60               | -                | Currently<br>Unknown | -                |
| Est. % Reefs under<br>immediate threat of loss   | -                | -              | -                | -                | -            | -                | <10              | -                | Currently<br>Unknown | -                |
| Est. % Reefs Under Long-<br>Term Threat of Loss  | -                | -              | -                | -                | -            | -                | <25              | -                | Currently<br>Unknown | -                |
| <b>Overall Reef Condition</b>  |                  |                |                  |                  |              |                  |                  |                  |                      |                  |
| No. of Hard Coral Species  | 185              | 111            | 590              | 400              | 64           | 464              | 197              | 250              | Unknown              | 400              |
| Very Healthy (>75% LC cover<br>or equivalent measure)  | 10↔ <sup>1</sup> | No new<br>data | 3↓ <sup>2</sup>  | 10↓ <sup>3</sup> | Not<br>known | 1↔ <sup>4</sup>  | 0↔ <sup>5</sup>  | 18↑ <sup>6</sup> | Not<br>reported      | 0↔ <sup>7</sup>  |
| Healthy (50–75% LC cover<br>or equivalent measure)   | 20↔ <sup>1</sup> | No new<br>data | 21↓ <sup>2</sup> | 30↓ <sup>3</sup> | Not<br>known | 9↑ <sup>4</sup>  | 10↑ <sup>5</sup> | 18↑ <sup>6</sup> | Not<br>reported      | 1↓ <sup>7</sup>  |
| Fair (25–50% LC cover or<br>equivalent measure)  | 60↔ <sup>1</sup> | No new<br>data | 42↑ <sup>2</sup> | 40↑ <sup>3</sup> | Not<br>known | 50↓ <sup>4</sup> | 20↑ <sup>5</sup> | 29↓ <sup>6</sup> | Not<br>reported      | 70↑ <sup>7</sup> |
| Poor/Very Poor (<25% LC<br>cover or equivalent measure)  | 10↔ <sup>1</sup> | No new<br>data | 34↑ <sup>2</sup> | 20↑ <sup>3</sup> | Not<br>known | 40↓ <sup>4</sup> | 70↓ <sup>5</sup> | 35↓ <sup>6</sup> | Not<br>reported      | 20↓ <sup>7</sup> |
| <b>Reefs at Risk 2002 (Integrated Threat Index)</b>  |                  |                |                  |                  |              |                  |                  |                  |                      |                  |
| % Low  | 79               | 0              | 14               | 13               | 44           | 2                | 0                | 23               | -                    | 4                |
| % Medium   | 16               | 0              | 39               | 44               | 36           | 27               | 0                | 24               | -                    | 22               |
| % High   | 5                | 90             | 46               | 38               | 20           | 63               | 100              | 51               | -                    | 49               |
| % Very High  | 0                | 10             | 1                | 4                | 0            | 7                | 0                | 1                | -                    | 25               |
| <b>Expert Projections in Ranking of the 5 R@R Threats Indicators (2008 VS 2002 Assessment)</b> |                  |                |                  |                  |              |                  |                  |                  |                      |                  |
| Coastal Development  | High#            | High#          | Low              | High#            | Low          | High#            | High             | Low              | Low◇                 | Low-Med          |
| Marine-Based Pollution   | Low              | High#          | Low              | Low              | Low          | High#            | High             | Low              | Low◇                 | Low-Med          |
| Sedimentation  | Low              | High#          | Low              | Low              | Low          | Low-Med          | High▲            | Low              | Low◇                 | Med-High         |
| Over-fishing   | Low              | High           | Med-High         | Med-High         | Low-Med      | Med-High         | Low▲             | Low-Med          | Low-Med◇             | Med-High         |
| Destructive Fishing  | Low              | High           | Med-High         | Med-High         | Low-Med*     | Med-High         | Low▲             | Low-Med          | Low-Med◇             | High             |

**BN:** Brunei; **KH:** Cambodia; **ID:** Indonesia; **MY:** Malaysia; **MM:** Myanmar; **PH:** Philippines; **SG:** Singapore;

**TH:** Thailand; **TP:** East Timor; **VN:** Vietnam

1 Data based on 2004 status report - reefs not expected to have changed since 2004

2 2007 Data from COREMAP Long-Term Monitoring Site; arrow indicates direction of change

3 2007 Data from UM, UMS, MoNRE, RCM, SIP, SP using LIT and Reef Check; arrow indicates direction of change

4 2004–2007 Data summaries from various projects; arrow indicates direction of change

5 2006–2008 Data from country-wide surveys; arrow indicates direction of change

6 2006–2007 Data from country-wide manta-tow surveys; arrow indicates direction of change

7 2002–2005 Data extracted from UNEP/SCS Project's GIS Database for 10 sites

\* Indicates updated country estimates based on GIS data; arrow indicates direction of change in updated value

# Indicates a change in threat level compared to the 2002 assessment; arrow indicates direction of change

▲ Threat indicator rankings based on local expert opinion

◇ Threat indicators assessed based on authors' opinions from preliminary data collected from East Timor surveys in 2004

**The data compiled in this table are based on direct monitoring data and national expert opinion and reflect the status of the reefs in the Southeast Asia Region**

## CORAL REEF DIVERSITY

Parts of Indonesia, Malaysia and the Philippines, together with Papua New Guinea, Solomon Islands and Timor-Leste constitute the 'Indo-Pacific Coral Triangle', a biodiversity 'hot spot' containing 500 or more species of reef-building coral and high fish diversity. The Coral Triangle is considered the epicentre of global marine diversity and abundance, however, these resources are under serious threat with increased exploitation fuelled by an exploding human population. This was the catalyst for the formation of the 'Coral Triangle Initiative' (p. 55). Corals, fishes, molluscs and lobsters all have maximum species richness in the Coral Triangle, with richness falling rapidly moving east across the Pacific, and less rapidly to the west across the Indian Ocean.

Despite the widespread destruction of coral reefs and the continuing threats to the reefs within and adjacent to the Coral Triangle, it is unlikely that any hard coral species have become extinct and coral species diversity is still high in all SEA countries. However, this may not be the case for other taxa like fishes, molluscs, echinoderms and other invertebrates. Most coral species have a widespread range in the region, whereas all lobster species and half the fish and snail species have relatively restricted geographic ranges, which indicate that reef degradation could lead to associated extinction of other taxa.

Hard coral diversity remains high in Indonesia, Philippines, Malaysia and Vietnam, with almost 600 species recorded in Indonesia. Many site specific hot spots of coral diversity (with more than 200 species of hard coral) occur in all SEA countries, with most hot spot areas occurring on deeper offshore reefs. However, there are more than 250 hard coral species in a small, shallow reef area of Singapore that is subject to high sedimentation rates. Similar coral species diversity occurs in sedimented waters along the northern coast of Pulau Bintan, Indonesia.

|   | BN | KH  | ID  | MY  | MM | PH     | SG  | TH  | TP  | VN  |
|---|----|-----|-----|-----|----|--------|-----|-----|-----|-----|
| <b>Total number of actively managed MPAs</b>  | 6  | 2   | 114 | 83  | 6  | 339    | 3   | 23  | 0   | 36  |
| <b>Total number of MPAs with coral reefs</b>  | 3  | 1   | 38  | 43  | 2  | 294    | 2   | 16  | 1   | 4   |
| <b>Total number of MPAs established ≤5yrs</b> | 0  | 0   | 12  | 0   | 0  | Unk    | 0   | 0   | 1   | 21  |
| <b>% of Reefs within MPAs</b>                 | 0  | Unk | 9%  | 7%  | 2% | 1%     | 0   | 50% | Unk | 11% |
| <b>% of MPAs with good management rating</b>  | 0  | 10% | <3% | 16% | 0  | 20–30% | 50% | 18% | 0   | 8%  |

*BN: Brunei; KH: Cambodia; ID: Indonesia; MY: Malaysia; MM: Myanmar; PH: Philippines; SG: Singapore; TH: Thailand; TP: East Timor; VN: Vietnam Unk = Unknown*

***This table summarises the status of MPAs in SEA (data extracted from 'Coral Reef MPAs of East Asia and Micronesia, 2007'.)***

## **SOCIOECONOMIC MONITORING**

Socioeconomic monitoring has occurred throughout Southeast Asia since 2004, particularly Indonesia and the Philippines. More than 9000 households and individuals have been surveyed, representing 40 communities: 21 in Indonesia; 27 in the Philippines; 2 in Thailand; and 3 in Vietnam. More than half the households are dependent upon fishing for their primary income, clearly demonstrating the importance of healthy coral reefs and fisheries to coastal villages. Unfortunately, these households also indicated a decline in resource conditions. While it is difficult to compare information across sites due to the different questions asked and choices provided, some trends are evident; most of the identified threats in Southeast Asia are in-water threats such as over-fishing, destructive fishing such as cyanide fishing, dynamite fishing, and use of fine mesh nets. Broader scale threats such as climate change and land-based sources of pollution were rarely mentioned, indicating a disconnect in local perceptions of the most severe threats facing the region. Socioeconomic monitoring (SocMon) training programs by NOAA and Conservation International, Philippines, have increased capacity in the region, especially in the Philippines, but more training is required.

## **MANAGEMENT AND CONSERVATION**

Management and conservation of coral reefs have generally improved in SEA within the last 10 years, with increased awareness from legislators, resource management agencies and the public. Numerous local and grassroots organizations have been established to address coral reef conservation and management concerns, thereby complementing existing institutional programmes. These include Reef Check Indonesia, The Indonesian Coral Reef Foundation (TERANGI), Malaysian Coral Reef Society (CoRal Malaysia), Reef Check Malaysia, Reef Check Philippines, Blue Water Volunteers, Singapore and Green Fins Thailand. In addition, The Nature Conservancy Southeast Asia Center for Marine Protected Areas (SEACMPA), World Commission on Protected Areas (WCPA) and UNEP have raised the profile of MPAs, with many projects being initiated to focus on establishing a network of MPAs in Southeast Asia, and improving the management effectiveness of existing MPAs.

A 2005–2007 collaborative effort between The WorldFish Center (ReefBase Project) and Japan Wildlife Research Center (JWRC), funded by the Japanese Ministry of the Environment, updated the regional coral reef MPA database to produce the report, 'Coral Reef MPAs in East Asia and Micronesia', that showed an increase in MPAs with coral reefs in SEA from 178 in 2003 to 403 in 2007. Despite the increased number of coral reef MPAs, many of these remain largely ineffective and unmanaged.

## **REGIONAL PROGRAMMES**

Numerous regional programmes have been implemented recently on conservation of coastal habitats, including coral reefs. The UNEP/Global Environment Facility South China Sea (UNEP/GEF SCS) project, 'Reversing Environmental Degradation in the South China Sea and Gulf of Thailand', runs from 2002 to 2009 in Cambodia, China, Indonesia, Malaysia, Philippines, Thailand, and Vietnam. The project includes a habitat component to establish a network of demonstration sites for coral reef, mangrove, seagrass habitats and wetlands around the region. One of the coral reef demonstration sites is highlighted on p. 144 (see [www.unepscs.org](http://www.unepscs.org)).

The WWF Sulu-Sulawesi Marine Ecoregion (SSME) Conservation Programme was launched in 1999 in partnership with Indonesia, Philippines and Malaysia. The goals involve planning for the conservation of the SSME through the formation of 50-year conservation Biodiversity Vision and the implementation of immediate conservation actions on the ground. The countries are the main drivers, working together to facilitate the establishment of interim governance mechanisms to ensure coordination in the development of the Ecoregion Conservation Programme (see [www.panda.org/about\\_wwf/where\\_we\\_work/ecoregions/index.cfm](http://www.panda.org/about_wwf/where_we_work/ecoregions/index.cfm)).

In 2006, the University of the Philippines Marine Science Institute became one of 4 global Centers of Excellence under the GEF Coral Reef Targeted Research and Capacity Building Management Project that will improve infrastructure in the centres to promote scientific research to address local coral reef-related problems, provide training and help other working groups in their research (see [www.gefcoral.org](http://www.gefcoral.org)).

To address the impacts of the diving and snorkelling industry on the coral reef habitats, the Coordinating Body for the Seas of East Asia (COBSEA) initiated a Green Fins Programme in 2004 'To protect and conserve coral reefs by establishing and implementing environmentally friendly guidelines to promote a sustainable diving tourism industry'. The programme involves partners from Thailand, Philippines and Indonesia; countries with large diving and snorkelling tourist industries. The programme aims to involve dive operators as partners in the protection, conservation and sustainable use of coral reefs, and to raise the environmental awareness of the diving community. This is achieved through capacity building, training, certification programmes and the distribution of educational materials (see [www.greenfins-thailand.org/mainPage.php](http://www.greenfins-thailand.org/mainPage.php)).

Coral reef restoration is viewed as a possible management measure to reverse coral reef degradation in SEA. A 4-year European Union project started in 2006 with Philippines, Thailand, and Singapore to develop suitable reef restoration practices for Indo-Pacific reefs. This involves the growth and maintenance of some coral species fragments and natural rubble recruits grown in aquaria and in field coral nurseries for subsequent transplantation to denuded or degraded reefs.

### **STATUS OF MANGROVES, SEAGRASSES AND FISHERIES: 2008**

There have been few national or regional assessments on the status of mangroves and seagrasses in SEA: a review of mangroves and seagrasses was published in 2006 during the UNEP/GEF SCS project. In contrast, there have been numerous fisheries assessments in the countries, and the region, with most of the information presented here coming from UNEP/GEF SCS reports.

**Mangroves:** There are 41 genera of true mangroves in the Indo-West Pacific region with SEA containing most of these. By 1998 it was estimated that more than 50% of the original mangrove area in SEA was lost, totalling a staggering 4.2 million hectares, with approximately 10% destroyed between 1993 and 2003 alone. Most of the losses were due to extensive coastline destruction and modification, including conversion to pond aquaculture, particularly for shrimp; clear felling of timber for woodchip and pulp production; land clearance for urban and port development; human settlements; and harvesting of timber products for domestic use.

**Seagrasses:** The region has 18 of the world's 60 seagrass species, however, destruction is similar to mangrove habitats: seagrass beds are subjected to threats from bottom trawling and extensive coastline destruction and modification. The loss of seagrass habitats is between 30–60% in Indonesia, Philippines, Thailand and Singapore but largely unmeasured in other SEA countries.

**Fisheries:** The seas of the region, especially the South China Sea and the Gulf of Thailand, still support a significant proportion of the world's fisheries and constitute the primary source of food protein security and income for most coastal communities in SEA. However, fisheries management is inadequate in most countries with problems arising from multiple jurisdiction conflicts, over-fishing and destructive fishing; and complicated by trans-boundary issues.

It is projected that increasing fishing pressure coupled with declining stocks of demersal fish species will increase the 'fishing down the food chain' effect, resulting in increased catches of small pelagic fish in the future. This can potentially lead to a downward spiral of declining fish populations and near-shore habitat deterioration, as small-scale coastal fisheries shift towards destructive fishing practices to maintain short-term income and food production.

The UNEP/GEF SCS Regional Working Group on Fisheries, partnered by the Southeast Asian Fisheries Development Center (SEAFDEC) is establishing a regional system of fisheries refuges in the South China Sea and Gulf of Thailand to build resilience in fisheries, especially focusing on critical links between fish stocks and their habitats. The 3 year project started in 2006 and involves Thailand, Vietnam, Philippines, Malaysia and Indonesia – countries with substantive coastal fisheries. The project aims to build resilience in the fisheries to counter high and increasing fishing effort; and to improve the understanding of ecosystem and fishery linkages amongst stakeholders, including fishers, scientists, policy-makers, and fisheries managers as a basis for integrated fisheries and ecosystem and habitat management with improved capacity of fisheries departments and ministries.

## **CONCLUSION AND RECOMMENDATIONS: 2008**

Recent assessments of coral reef areas in Thailand and Singapore indicate that the previous global estimates probably exceed actual area about tenfold. A regional assessment of the actual coral reef area will provide crucial information to determine status of coral reefs in the region. Threats to coral reefs may be more significant if actual estimates of coral reef area prove to be much lower than the long-standing global estimate of about 100 000 km<sup>2</sup> for the region.

The Myeik Archipelago in Myanmar contains a large area of coral reefs, most of which are probably in pristine condition. In the face of the declining coral reef condition in many areas, these reefs of Myanmar could prove to be critical refuges for coral reef species. However, the status is largely unknown, and therefore mid- to long-term programmes are needed to assess Myanmar coral reefs, and recommend management measures to conserve these reefs.

Although coral reef surveys have been initiated in Cambodia and East Timor, they are occasional and not supported by in-country programmes. Assistance is needed for mid- (5 years) to long- (10 years) term monitoring programmes supported by in-country commitment.

There are numerous, small-scale coral reef monitoring programmes undertaken by various agencies within the region, employing a variety of survey techniques. A combination of these programmes provides a relatively comprehensive picture of the status of coral reefs within each country, however, there is insufficient integration in the information collected by the projects, making it difficult to prepare country-specific assessments. The tasks of GCRMN country coordinators to collate national status information are hampered by insufficient resources to maintain databases on on-going programmes. This could be solved at the regional level with the development of a region-specific meta-database and summary data coordination programme integrated within ReefBase to improve access of data by resource managers. Socioeconomic monitoring programs, shown to be successful in Indonesia and the Philippines, should be expanded to include the rest of Southeast Asia.

The first Asia Pacific Coral Reef Symposium (APCRS, similar to the European Coral Reef Symposium) was hosted in Hong Kong in 2006. This symposium fills a gap for the exchange of research findings and ideas among the coral reef community in this region, which has the largest area and highest coral reef biodiversity. Unfortunately, APCRS is largely unknown to the global community, and more support and acknowledgement is required to ensure it achieves adequate regional and global recognition. Ideally, the APCRS will become part of the ICRI agenda with additional support, starting with the second APCRS scheduled for 2010 in Phuket, Thailand.

#### **ACKNOWLEDGEMENTS**

The authors particularly acknowledge the UNEP/GEF SCS project, with these reports providing a large proportion of information on the status of mangroves, seagrass and fisheries.

#### **AUTHOR CONTACTS**

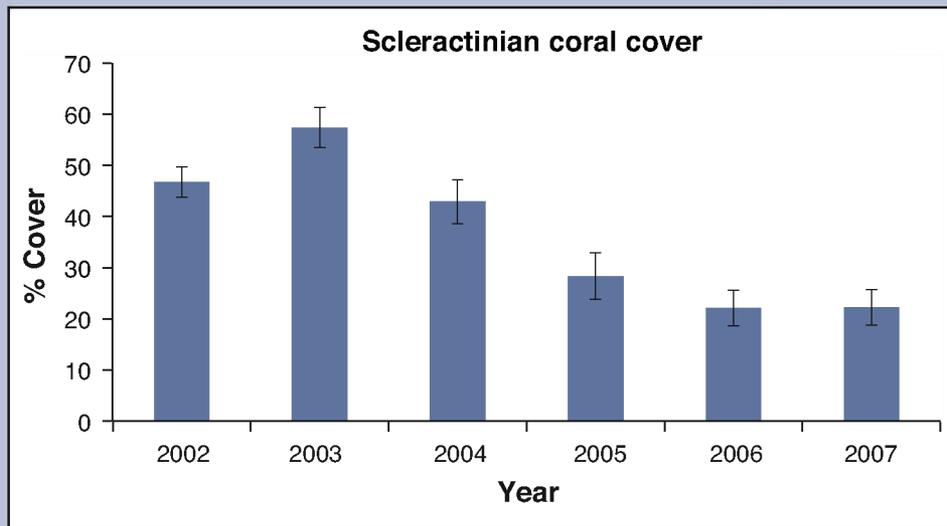
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#### **KEY SUPPORTING DOCUMENTS**

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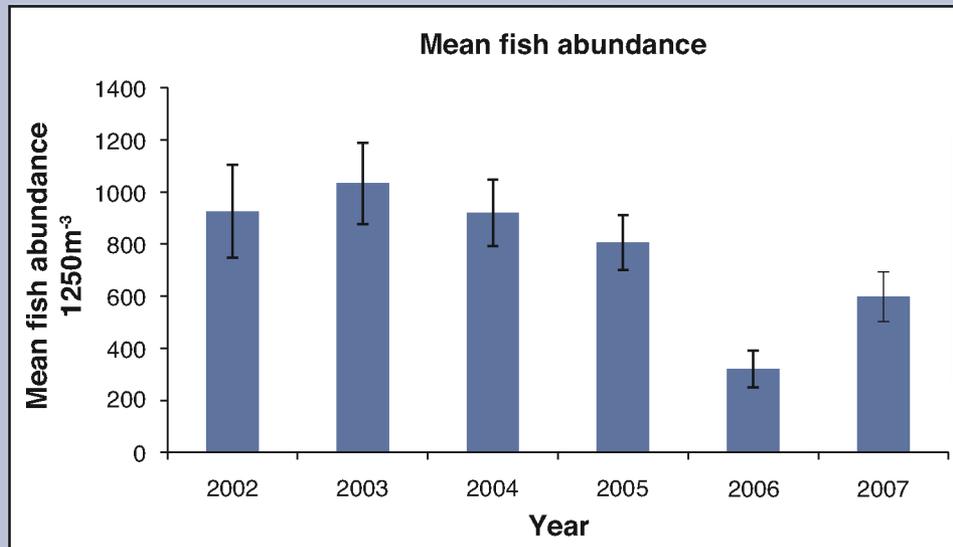
**REEF STATUS IN THE WAKATOBI MARINE NATIONAL PARK,  
INDONESIA 2002 -2007**

There are abundant coral reefs within the Wakatobi Marine National Park, south of Sulawesi, Indonesia, with at least 400 species of hard coral and 600 fish species (and still counting). This large park encompasses 4 of the Tukang Besi Islands: Wangi Wangi, Kaledupa, Tomia and Binongko. These findings are from Operation Wallacea which has assisted in establishing the Park for 11 years. Monitoring of 6 separate sites in the park using 9 by 50 m transects at 3 depths (1–2m; 2–6 m; 9–12 m) found a significant drop in coral cover at all sites within the park.



***This graph shows a general decline in hard coral cover from an average at 6 different locations of 49.7% (± 2.9) in 2002 to just 22.0% (± 3.5) by 2007. In 2002 the Hoga No-Take Area had the highest cover at 56.8% and Sampela showed the least cover with 32.6%. This is slightly lower than the 2007 highest cover, again in the Hoga NTA of 34.2%, with Sampela still having least cover at 11.0%. This is a 40% decrease in coral cover at the Hoga site and a 66% decrease at the most impacted site, Sampela.***

Genus richness of hard corals along the 50 m line transects has not really changed ( $12.0 \pm 0.2$  in 2002; and  $12.4 \pm 0.4$  in 2006, while the total cover dropped. The coral decline is predominantly due to increased sedimentation from mangrove removal, agar farming and reef-flat gleaning which is also damaging seagrass beds near villages. Over-exploitation of reef resources combined with destructive techniques such as blast and muro-ami fishing is also damaging the corals occurs in more remote areas.



***This shows that the mean abundance of fish was 935.9 (± 138.2) per 500m<sup>2</sup> in 2002, but has dropped by nearly two thirds to 326.4 (± 65.8) /500 m<sup>2</sup> in 2006; or an annual reduction of 13% per year from 2002. Similarly, the mean number of species observed also reduced from 49.32 (±3.59) /500 m<sup>2</sup> in 2003 to 33.07 (±3.82)/500 m<sup>2</sup> in 2006.***

Declines in fish diversity and abundance around Kaledupa are attributed to rapid expansion in fish fence traps around Kaledupa and Hoga islands since 2005, such that there is a direct correlation between the number of fish fences and the abundance of reef fish. These highly efficient fish traps remove both adult and juvenile fishes, with a cascading loss in future years. It is clear that if the over-exploitation from fish fences, blast and muro-ami fishing continues to increase, both the coral reefs and their fish populations will continue to decline, threatening the viability of the Wakatobi Marine National Park (from Steve McMellor, Coral Reef Research Unit, University of Essex, UK, [smcmellor@Lycos.co.uk](mailto:smcmellor@Lycos.co.uk)).

#### POST 2004 TSUNAMI RECRUITMENT IN MU KO SIMILAN, THAILAND

The 2004 tsunami scoured out about 2 m of sand and rubble at 30 m depth at Snapper Alley Point (8° 40'N, 97° 39'E). Within one month of the tsunami, green algae covered the bare rocks. Two years later the sand had not returned but there was considerable new settlement and growth of sea fans, soft corals, coralline algae and sponges on the bare rocks. A totally new community has been created out of the chaos of 2004 (from Suchana Chavanich, Department of Marine Science, Chulalongkorn University, Bangkok, Thailand, email: [suchana.c@chula.ac.th](mailto:suchana.c@chula.ac.th)).

### REEF MORTALITY EVENT AT HIN MUANG/HIN DAENG, THAILAND, IN 2007

A mass mortality event occurred in early 2007 on many reefs around the Thailand Andaman Sea provinces of Krabi, Trang, and Satun. The mortality coincided with abnormally low temperatures, around 23–24°C down to 30 m depth (normal temperatures are 27–29°C). Dive operators described brown plumes in the water and dead fish, invertebrates and soft corals, especially at Hin Muang and Mu Koh Ha reefs. The Phuket Marine Biological Center could not pinpoint the cause of death in samples from dive operators; however dissolved oxygen levels were very low (range 1.5 to 2 mg per litre; normal sea water is about 7 to 9); this was the probable cause for the die-off. The question was asked: why would offshore islands have such low levels of dissolved oxygen? The cold temperatures point to upwelling bringing low temperature and low oxygen water up from very deep water. These waters usually contain more nutrients which stimulate plankton blooms, possibly around these offshore islands. The cause of the upwelling possibly resulted from internal ocean waves that move towards the Andaman Coast and, in early 2007, such internal waves were observed at around 100 m depth and arriving at the surface with cold bottom waters. These waves may be related to large scale oceanographic changes with the Indian Ocean Dipole (similar to the El Niño Southern Oscillation in the Pacific) operating at the end of 2006 – sea level was higher in the western Indian Ocean, around Thailand, than in the east. This probably resulted in upwelling of cold, low oxygen water which stressed soft corals and other animals, resulting in death. Many corals in the Andaman Sea died during previous ENSO events in 1994–1995 and 1997–1998 (from Niphol Phongsuwan, Phuket Marine Biological Center, Thailand; [nph1959@gmail.com](mailto:nph1959@gmail.com)).

### MU KOH CHANG CORAL REEF DEMONSTRATION SITE

Mu Koh Chang National Park in the eastern Gulf of Thailand, was established in 1982 and is currently a new tourism destination receiving more than 1 million visitors per year. The Park was designated a Demonstration Site for Coral Reefs under the UNEP/GEF South China Sea project with the goal of removing or reducing causes of coral reef degradation by applying a new model of co-management in the area and restoring certain degraded areas for education and tourism purposes. The Thai Government is developing Mu Koh Chang as an important regional eco-tourism site. The project highlights the importance of co-ordination among government institutions, the private sector, and local communities for sustainable tourism development. The success of Mu Koh Chang management model could be applied to other areas with similar problems in Thailand and in other countries bordering the South China Sea.

Major achievements of the project include increased public awareness of the ecological importance of coral reefs; the establishment of a network of government institutions, private sectors and local communities for coral reef management and conservation; the development of a sustainable ecotourism program for Mu Koh Chang and the vicinity; capacity building; the development of alternative income generating programmes for fishermen; and providing support for coral reef monitoring and rehabilitation (from Thamasak Yeemin, Ramkhamhaeng University, Thailand [thamasakyeemin@hotmail.com](mailto:thamasakyeemin@hotmail.com)).

## 10. STATUS OF CORAL REEFS IN EAST AND NORTH ASIA (CHINA, HONG KONG , TAIWAN, SOUTH KOREA AND JAPAN)

TADASHI KIMURA, CHANG FENG DAI, HEUNG-SIK PARK,  
HUANG HUI AND PUT O. ANG

### ABSTRACT

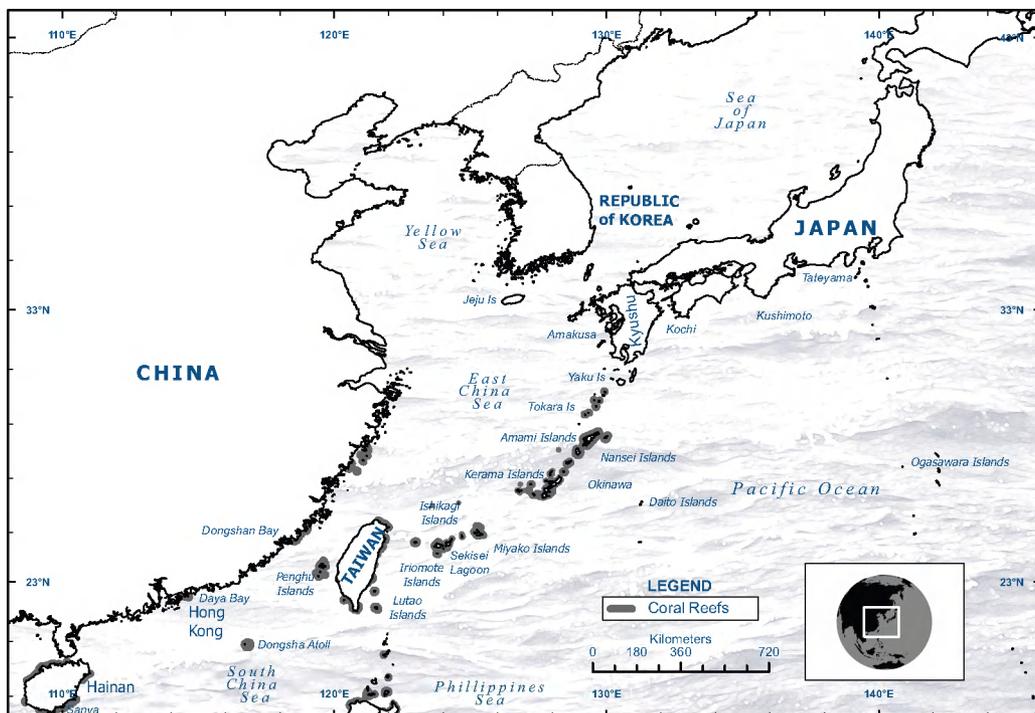
- Coral reefs in East and North Asian countries showed an overall decline caused by bleaching, crown-of-thorns-starfish and typhoons together with human stresses since 2004;
- Coral reef monitoring is well established in Japan, Hong Kong, Taiwan and Hainan Island in China. National and state governments support annual monitoring programs on coral reefs associated with local scientific networks in these countries. However, socioeconomic monitoring has not been established in the region;
- Some extensive research on corals was conducted in China and South Korea and regular monitoring has been planned;
- All countries have targeted MPA enhancement and integrated coastal management at local level to reverse the coral degradation;
- The 'Coral Reef MPAs of East Asia and Micronesia' database was developed in 2007 to collect and renew baseline information of MPAs in this region;
- Regional workshops on MPA networking are planned from 2008 to 2010 to achieve WSSD 2012 goals of enhanced MPA networks;
- East and North Asia and South-east Asian countries recognized a need for regional coordination and networking to improve conservation during Okinawa ICRS in 2004 and are establishing a regional core network of scientists;
- The network organized the first Asia Pacific Coral Reef Symposium in Hong Kong in 2006 and the second symposium will be held in Phuket, Thailand in 2010.

## INTRODUCTION

East and North Asian countries comprising mainland China, Hong Kong, Taiwan, Korea and Japan, lie to the north of the coral triangle of highest marine diversity. Countries, especially Japan and Taiwan, gain coral reef larvae from the warm Kuroshio Current that flows northward to Tokyo Bay, although coral distribution is patchy on that coastline and no true coral reefs form. Taiwan has 300 coral species and Japan has more than 400 species. Hainan Island, China, the southern-most part of the region (18–20°N), is quite tropical, especially in the south where there are well developed fringing reefs; these, however, are threatened by the rapid growth of tourism and development, increasing sedimentation and marine pollution. Only the southern part of Korea is influenced by a branch of the Kuroshio Current and corals are restricted to Jeju Island, the most southern island of South Korea. Soft coral is dominant in the area with few hard corals (16 species, most growing at Jeju Island).

Coral reefs are well developed around Hainan Island of China, Taiwan, and Ryukyu Islands of Japan and people rely on coral reef resources. The northern areas of Japan and Korea are seaweed dominant ecosystems with patchy coral communities but these are attractions for diving and snorkelling tourists. It appears that coral communities in these areas are expanding because of rising water temperatures. In contrast, macro-algal cover has increased in about half of the survey sites in Taiwan, accompanied by higher sedimentation loads and increased water turbidity, suggesting continuous reef degradation and a possible phase shift from coral-dominated to algal-dominated reef communities.

The 'Status 2004' report described China, Taiwan and Hong Kong as having healthy corals in the 1980s but noted that they were declining due to the human stresses of sedimentation and



sewage from land due to economic growth. There were some exceptions such as Yongxing Island and Xisha Island in China; Chinwan, Penghu Island, Hsiangjiaowan and Lutao in Taiwan. Fisheries resources were also declining rapidly due to destructive fishing practices and over-fishing. The coral reefs of Okinawa, Japan were seriously damaged by a crown-of-thorns starfish (COTS) outbreak in the 1970s and 1980s. Although corals had recovered well by the mid-1990s in Sekisei Lagoon, they had not recovered in Okinawa due to sedimentation from red soil erosion. In 1998 both healthy and non-healthy coral reefs were equally damaged after bleaching during high water temperatures. Since then, bleaching has occurred frequently to continually stress the coral reefs. In addition, COTS again appeared in large numbers at the Amami Islands in 2000 and spread by the Kuroshio Current to the Okinawa area and further north.

The longest monitoring program in this region started at Sekisei Lagoon, Okinawa, Japan in 1983; this has continued to 2008 as part of a national program of ecosystem monitoring. From 2003 it has expanded to all major coral habitats in Japan to monitor coral reef health. The Taiwanese Coral Reef Society started Reef Check monitoring in 1997, with government funding support since 2001. In 1997 Hong Kong also started coral monitoring at MPA sites by the Chinese University of Hong Kong and the government agency. Although regular coral monitoring has not been conducted in Korea, the government is planning a monitoring program on soft coral habitats at Jeju Island in 2008. Although some foreign researchers have made sporadic surveys on corals in China since the 1950s, coral monitoring only started at Hainan Island in the early 2000s.

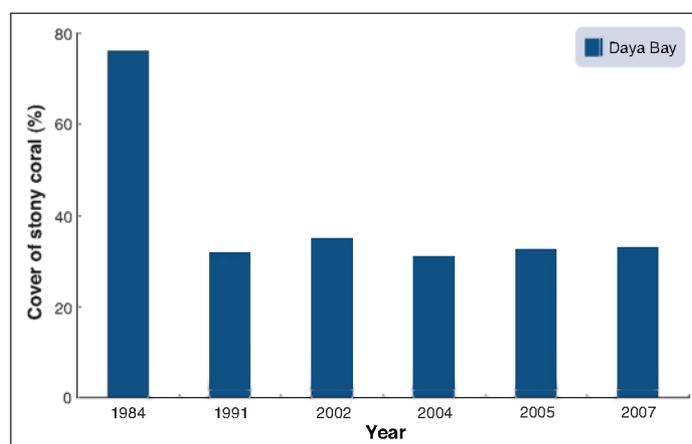
Coral conservation and management have improved in Japan since the establishment of ICRI in 1994. Taiwan recognized the importance of coral conservation and management in 1997 and started establishing MPAs. Coral research in China was emphasized when Hainan Island was designated as a National Park in 1990 and coral studies have gradually improved, along with more focus on National Parks and coastal conservation. Although there are differences in progress on management activities, participation in the GCRMN has improved national coral conservation. The GCRMN framework has also enhanced inter-regional cooperation between SEA and East and North Asia, formulating a larger network of the two regions.

## STATUS OF CORAL REEFS: 2008

**China:** The condition of Chinese coral reefs was regarded as quite healthy before the 1980s, with coral cover exceeding 70% at Luhuitou in Sanya in the 1960s and at Yongxing Island and Xisha Island in the 1970s. For example, coral cover at Daya Bay was 76% in 1984. However, the environment of coral reefs has been changed by rapid economic growth, such that coral cover at Daya Bay dropped to 32% in 1991. Since 1991, coral cover has remained stable around 30% until 2007 as the figure on the next page illustrates. An intensive coral survey at Sanya National Coral Reef Natural Reserves in 2006 also showed declining coral cover since 1984.

**Taiwan:** Coral reefs at 49 sites in 9 regions were surveyed in Taiwan between 2004 and 2007 using Reef Check methods and video transects. Hard coral cover showed wide variability, with the highest cover at North Sanxiantai on the east coast of Taiwan (66.7%), Yehyo of Lanyu (50.2%), Chaikou of Lutao, and eastern reef slope of Dongsha Atoll (52.5%). If soft coral cover is included, flourishing coral reef communities were observed at several sites of Lutao, Lanyu, and Dongsha Atoll. The northern and eastern reef slopes of Dongsha Atoll show the most scenic underwater images, with coral cover of 78% and 85% respectively. However, coral cover at 24

of the 49 sites was lower than 30%, indicating that these reefs, which occur in favorable tropical environments in the south and south-east of Taiwan, were under severe stress or had been heavily damaged. The lowest coral cover sites were less than 10%: all were in the lagoon of Dongsha Atoll which was severely damaged by mass coral bleaching in 1998. Overall, monitoring is showing a general trend of declining coral cover on Taiwanese coral reefs. Macro-algal cover has increased at about half of the survey sites in parallel with higher sedimentation loads and water turbidity. This suggests that reef degradation is continuous and a possible phase shift from coral-dominated to algal-dominated reef communities. Though a few sites in the lagoon of Dongsha Atoll showed signs of recovery from the 1998 bleaching event, mass bleaching was again encountered in 2008 on many of the already stressed coral reefs. Coral reefs in Kenting have experienced the most severe bleaching with over 50% of coral suffering from bleaching in the shallow waters. The lagoon of Dongsha Atoll is also heavily impacted by the 2008 bleaching event.

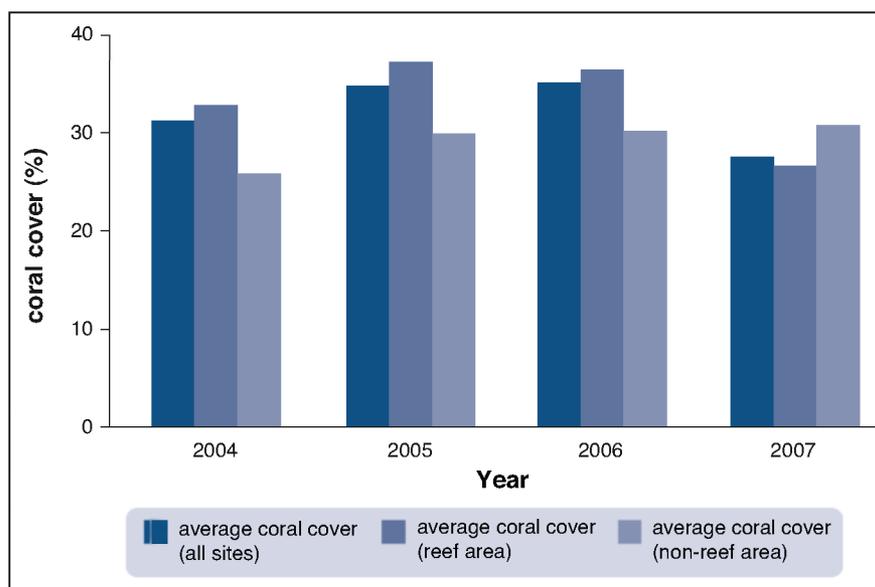


**Coral cover at Daya Bay, Guangdong (just north of Hong Kong), China, was particularly healthy in 1984 with 76% cover, but has dropped to around 30% and remained relatively unchanged for the last 16 years. In order to compare coral percent cover between different years, only cover data in the middle part of the Daya Bay (Dalajia and Xiaolajia islands), were chosen because all studies covered these two islands.**

**Hong Kong:** A long term coral monitoring programme has been established in A Ma Wan, Tung Ping Chau Marine Park, Hong Kong, since May 1997. The coral community has experienced repeated tropical cyclones: between 1997 and 1999 the highest frequency of severe tropical cyclones to hit Hong Kong, including the strongest cyclone since 1984. *Cyphastrea serailia*, *Goniopora lobata*, *Montipora peltiformis* and *Pavona decussata* were the dominant species most affected by the cyclones; since then there has been a significant shift in the coral community structure from *Platygyra-Goniopora* to *Pavona-Platygyra*. The original coral community was relatively stable and resistant to short-term disturbances but not to repeated long-term ones.

**Japan:** Japan has had a national coral reef monitoring program since 2003 at 22 sites with 2 occasional sites assessed every 5 years. Coral cover declined from 2005 to 2007 in coral reef and

non-reef areas; the average of all sites was 30.4% in 2004, increasing to 33.9% in 2005, decreasing to 32.4% in 2006 and further decreasing to 27.1% in 2007. The major causes for this decline were outbreaks of COTS, typhoons, and bleaching from high water temperatures. The first outbreak of COTS was in Amami around 2000 and annual monitoring has shown increasing numbers in Sekisei Lagoon since 2000. Outbreaks have also occurred at Kerama Islands, Yabiji and Sekisei Lagoon from 2004 to 2006. However, this outbreak of COTS seemed to end in 2007 at Kerama Islands with coral cover starting to increase. COTS populations at Amami Islands and Yabiji were still high in 2007 and coral cover was declining. COTS have also damaged coral communities at a non-reef site in Kushimoto in 2004 and 2005. In 2004 a strong typhoon hit Kushimoto and coral cover was further decreased. Sekisei Lagoon had typhoon damage in 2004 and 2005: there was no coral growth during these 2 years. There was large-scale bleaching in Sekisei Lagoon in 2007 and coral cover declined rapidly. Okinawa still had quite low coral cover in 2007, showing a gradual trend in declining coral cover since 2004.



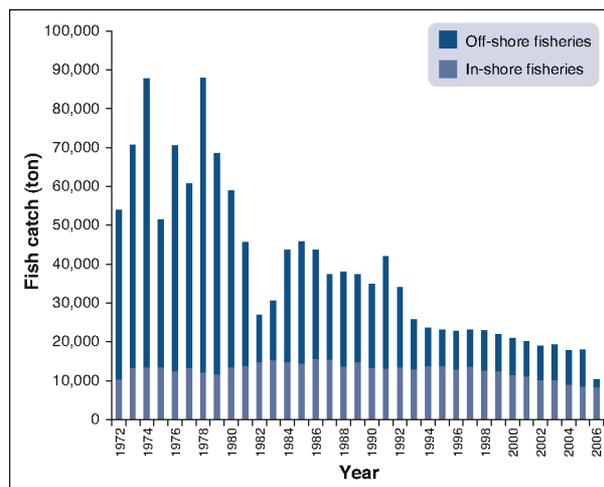
*This chart shows that coral cover, as an average of all monitoring sites in Japan between 2004 and 2007, has stayed relatively constant despite crown-of-thorns starfish plagues and typhoons. However, coral cover is still much less than it was before the 1998 mass coral bleaching depleted many coral reefs.*

**South Korea:** Since 1974 the distribution of corals has been surveyed and now 137 species of corals have been reported with 3 additional species added in 2007: 16 species are listed as stony coral and 15 coral species have been designated as preservation species by the Natural Environment Preservation Act. Notably, 67 coral species are restricted to Jeju Island. Korea has designated 11 areas as MPAs but only the southern parts of Jeju Island have a focus on corals. In some parts of Jeju Island algae have replaced soft corals since 2000: this may be due to changes in current speeds following the construction of the harbor extension.

## STATUS OF REEF FISH AND FISHERIES

**China:** A survey in Hainann in 2006 noted 102 reef fish species, mainly *Pomacentridae*, *Labridae*, *Chaetodontinae*, *Apogonidae*, and *Scaridae*. The dominant species were *Dascyllus reticulatus*, *Pomacentrus* sp., *Apogon* sp., *Stegastes obreptus*, *Abudefduf sexfasciatus* and *Chromis notata*. Fish body lengths ranged from 1 to 10 cm, except 31 individuals which were more than 20 cm long, and 9 more than 30 cm (these were less than 1% of the total number of fish observed). Only 31 high commercial value grouper fish were observed and only 2 were more than 20 cm long. No other large commercial species were found. Coral reef fish density was low in the Sanya coral reef protected area, with average fish density being about 1 fish per m<sup>2</sup>. Fish numbers and density were also low around Xi Island and Dong Island of Sanya Bay, and Xipai of Yalong Bay, where the coral reefs were severely damaged. Species diversity and density of reef fish was highest in Yalong Bay (Dongpai and Yezhu Island); followed by Luhuitou, Da Donghai and Xiao Donghai, near the Sanya River and Damaoshui River estuaries. Thus there is serious fishing pressure and over-fishing in all Sanya waters: there were also low numbers of giant clam (*Tridacna* sp.) and cowries (*Mauritia* and *Cypraea* spp.) which also suggests over-fishing.

**Taiwan:** Commercially important fish species were in low abundance at all sites from 2004 to 2007. Only at Dongsha Atoll, where fishing is restricted and enforced by Taiwan's Coast Guard Administration, were there any large sized jacks. Indicator species such as humphead wrasse, bumphead parrotfish, and barramundi were absent from all 49 reef sites monitored. Groupers were recorded at a few sites at Kenting and Dongsha Atoll, but were of small size and in very low abundance. Snapper abundance was also very low (1–2/100 m<sup>2</sup>) at a few sites. Similarly, butterflyfish abundance was much lower than most Indo-Pacific reef sites (1–4/100 m<sup>2</sup>), compared to overall fish abundance (6–8/100 m<sup>2</sup>). These low densities of fish indicate over-fishing to supply seafood markets and the aquarium trade.



**Fish catches in Okinawa Prefecture, Japan have steadily declined from a peak in the 1970s for both in-shore and off-shore fisheries (data from Statistical Information Center of Ministry of Agriculture, Forestry and Fisheries: <http://www.pref.okinawa.jp/suisan/4topic/1suisangyou/6catch-syurui.xls>)**

**Japan:** In the Okinawa prefecture, the main area of coral reef distribution, total fish catch has rapidly declined since 1978 and the coastal fisheries catch has also decreased gradually since 1998. The Ministry of the Environment and the Subtropical Research Institute in 2006 reported that stocks of *Lethrinus nebulosus*, *Plectropomus leopardus*, and *Epinephelus merra* have been decreasing in Okinawa, based on catch and effort ratios. Local fishermen have also reported resource degradation and reduced fish catches.

**Korea:** Approximately 250 species of fish have been identified at the Jeju Island MPA including some tropical species that appear to be increasing gradually because of warming waters reaching Korea.

### STRESS AND DAMAGE TO CORAL REEFS

**Sediments and nutrients:** The Biodiversity Survey in China 2006 showed that river discharges to Yulin Bay and Sanya Bay caused significant damage to the surrounding coral reefs compared to Yalong Bay which has little runoff and where coral reefs are healthy. Increased runoff and consequent algal blooms are the major issues in the Sanya area. Coastal areas of Taiwan have been under extensive infrastructure development with the growing populations including aquaculture, agriculture, resort building, etc. As a consequence, soil erosion is high, leading to frequent landslides in rain and typhoon seasons and massive sediment flows into reef areas. Monitoring has shown clear reef damage adjacent to drainage systems by coastal highway construction. Sewage from most coastal towns and villages is often discharged over reefs without proper treatment; sewage and sediment pollution is increasing rapidly and resulting in algal proliferation and coral losses. A major disturbance to coral reefs in Japan is red soil erosion from rivers, coastal constructions and farms in Okinawa. Prefectural regulations control the soil discharges from construction sites, but runoff from the agricultural farms remains a major issue. Untreated sewage from coastal villages and nutrient discharge from the livestock industry also stress the reefs. Major threats to marine life, including reefs in Korea, are suspended material from the land due to coastal development and construction, and land-based organic pollution.

**Development Damage to Coral Reefs:** According to a report by Renlin Zou, 95% of live corals on fringing reefs around Hainan Island were destroyed before the Sanya coral reef natural reserve was established by China. Many coral reefs were mined for construction materials and cement, and live corals were collected as souvenirs; resulting in huge reef damage, with more than 200 m coastal erosion, and with the loss of 200 coconut trees and seawater intrusion into Bangtang village, Wenchang County. Extensive coral destruction by seaweed culture was observed in Qianghai County. Coral dredging is also another issue in Sanya City. Coastal development including reef reclamation, coral dredging, construction of artificial reefs and breakwaters cause the main damage to corals in Japan. Anchoring by large cargo ships also damages coral reefs in Okinawa. Port construction and land reclamation are considered the major potential threats to the MPA of Seogwipo in Korea.

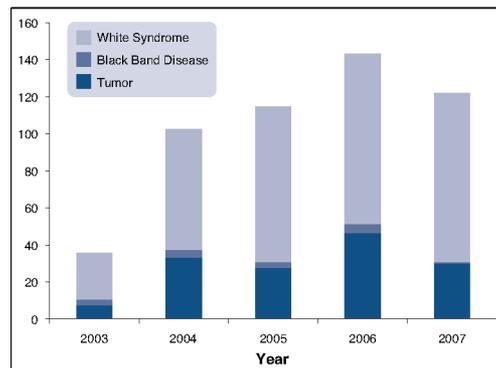
**Destructive Fishing and Over-fishing:** All coral reef fishes surveyed in Sanya, China, in 2006 were small (length range, 1–10cm) with few target fish – clear indications of major over-fishing. Although blast-, poison and electro-fishing have been officially banned, these illegal fishing practices still occur, especially in southern and eastern Taiwan and offshore islands. Gill nets are used frequently in most reef areas and many nets are lost and continue ‘ghost’ fishing.

Bottom-trawlers have caused severe damage to coral reefs in Penghu Islands and bycatch is a serious problem as fishers are using smaller mesh nets to boost catches. Over-fishing is very obvious as most commercially important fish are absent from most reefs. There are preventive measures, including patrols by the coast guard in protected waters to reduce illegal fishing, however, the effectiveness of law enforcement varies considerably. Dynamite and cyanide fishing were common in Japan after World War II until the early 1970s, but these are not apparent now. However, spear fishing with scuba tanks and hookah is degrading fisheries resources. Over-fishing and unsustainable fishing methods, such as spearing, are still common activities in Korea although they are decreasing. Commercial fish farming is increasing and may result in pollution.

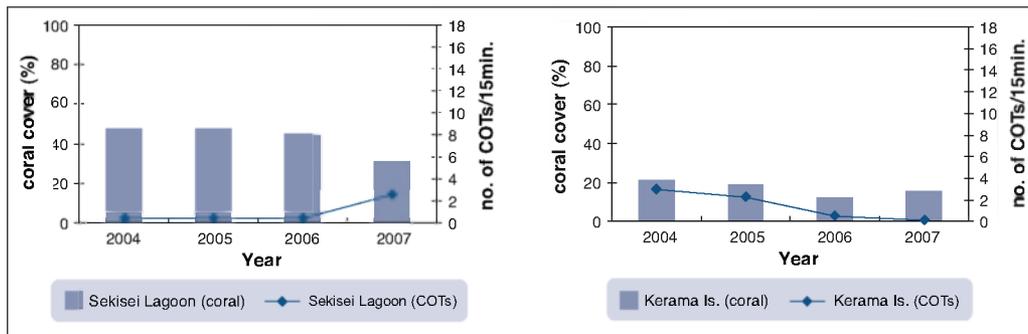
**Marine tourism activities:** Marine recreation is increasing in popularity, especially in southern Taiwan and offshore islands. This fast growing tourist population is adding more stress to reefs with development to expand tourism infrastructure ultimately leading to terrestrial runoff, poor water quality and solid wastes. Trampling and mechanical breakage of corals by boats, snorkellers and scuba divers is another serious problem, and tourists demand quality seafood thereby putting greater pressures on diminishing fish stocks. Some diving areas have been closed to allow recovery from tourist impact at Kerama Islands, Japan, and the community in Shiraho village has developed guidelines for snorkellers to reduce coral damage. Unsustainable tourism is also a major threat for reefs in Korea including recreational diving and a tourist submarine which physically damages marine organisms, especially soft corals. However, the government is preparing a management plan to reduce tourist impacts.

### CORAL BLEACHING AND DISEASES

There have been no reports of serious coral bleaching or coral diseases recently in China, however, corals in shallow waters in Weizhoudao, Guangxi Zhuang Autonomous Region die regularly with the cause apparently being high water temperatures in summer and low temperatures in winter. Mass coral bleaching was observed in Kenting, southern Taiwan, in the summer of 2007 due to prolonged sea surface temperatures over 29.5°C beginning in late June. By late July over 45 species of hard corals, mainly *Millepora* and *Acropora* spp., were bleaching with approximately 70% of coral colonies displaying various levels of bleaching. No disease outbreaks were reported prior to 2004, however, some large-scale diseases were observed in 2005 due to pollution caused by increasing marine tourism. The most severe epidemic is black disease at northern Green Island caused by a sponge, *Terpios hoshinota*, that proliferates in polluted waters. More than 50% of corals were overgrown by the sponge, irrespective of the coral species. Corals in Kenting reefs were infected by an unknown pathogen with the surface covered in pink spots. The linkage between polluted waters and declining coral health and growth is becoming much more evident. In Japan, high temperature coral bleaching occurred in Ogasawara in 2004 and Sekisei Lagoon in 2005 and 2006 but the damage was not serious. Moderate to severe coral bleaching was observed in Iki, Miyako and Ishigaki islands, Yabiji and Sekisei Lagoon in 2007. The most severe losses were in Sekisei Lagoon with a 14% loss in coral cover from 2006. This was much more serious than the 1998 bleaching damage. In 2004 and 2005 bleaching caused by low temperature was recorded in Sekisei Lagoon during winter when coral colonies on the upper-reef flat bleached and died during the low tide at night when the air temperature went down to 14°C. Low temperature bleaching also occurred in Kushimoto in 2005 at 14.4°C: the highest bleaching rate was 90% with 50% mortality at the upper reef. Coral diseases have been frequent in Sekisei Lagoon since 2003, and recorded at the Kerama Islands, Miyako Island and Kushimoto in 2007. Korea has no record of coral bleaching.



*The incidence of observed disease on coral colonies on reefs in Japan has increased between 2003 and 2007. The data combines reports of 3 coral diseases: white syndrome, black band disease and coral tumors.*



*These graphs compare average coral cover (as %) and the number of crown-of-thorns starfish (average of observations during a 15 minute swim) at the Japanese monitoring sites in the Sekisei Lagoon, south of Ishigaki Island, and in the Kerama Islands, west of Okinawa from 2004 to 2007. The decline in coral cover at both sites was largely due to the COTS predation.*

**Coral predators and Invasive Organisms:** Outbreaks of COTS in 2005 were recorded at Sanya (Yalong Bay in particular) and Xisha Islands in China, as well as at Da Donghai and Xiao Donghai and Yalong Bay (especially at Xipai) in 2006. There are fewer COTS in Dongpai, Yalong Bay, but *Drupella* was often found in these areas. Fortunately, COTS are rarely observed on reefs in Taiwan. A previous outbreak of a sea anemone, *Condylactis nanwanensis*, in Nanwan Bay, southern Taiwan, overgrew and killed corals; this has now greatly diminished. An outbreak of COTS started around 2000 at Amami Islands at the northern end of the true coral reefs in Japan. COTS have increased and coral cover has shown a clear decline between 2004 and 2007: with large numbers of COTS observed at Kerama Islands, Miyako Island, Yabiji, Ishigaki Island and Sekisei Lagoon. The outbreak continued in those areas during 2007 except on Kerama Island when numbers diminished in parallel with the loss of coral colonies. In Sekisei Lagoon, large numbers of a second generation of COTS were observed in 2007, as well as at the Daito Islands (ocean islands 340 km east of Okinawa Island). These COTS outbreaks spread northwards with the Kuroshio Current to Amakusa, Shikoku and Kushinoto; there was a significant drop in coral cover between 2004 and 2005 in Kushimoto. No outbreaks of invasive organisms have been reported in Korea.

**Natural disturbance on coral reefs:** Coral reefs in Taiwan are battered frequently by typhoons from May to October, especially on southern, eastern and offshore island reefs where corals are broken or covered with sediment. Increasing sea surface temperatures will threaten all coral reefs in the region, especially those under other stresses. Japan also has several typhoons every year, with major damage to corals in northern Sekisei Lagoon in 2004. Strong typhoons destroyed corals at Ishigaki Island, Sekisei Lagoon and Ogasawara in 2005 and 2006. Typhoons reach as far as the Korean peninsular but there are no records of serious coral damage from 2005 to 2007.

### **CORAL REEF MANAGEMENT STATUS IN EAST AND NORTH ASIA**

In the East and North Asian region Taiwan and Okinawa, Japan, have actively conducted coral reef research and conservation activities since the 1980s with regular monitoring including an Integrated Coastal Zone Management project at Sekisei Lagoon in Okinawa. Hong Kong has also had active coral monitoring and conservation in MPAs. On mainland China there had been limited coral reef research (for specific interests) in 1980s and 1990s, but in the early 2000s China focused coral studies on conservation and management of coastal resources especially at Hainan Island which is a National Coral Reef Reserve. However, effective MPA management has not been established. On the other hand, coral reef management has improved in South-east Asia since 2002 with the World Commission on Protected Areas SEA Marine Working Group developing a Regional Action Plan for 2002–2012; however, progress in implementation varies considerably between countries. Therefore, in 2008 the Japanese government launched a new initiative on MPA enhancement to support the goal for MPA networks throughout Asia. A series of workshops on MPA networking has been planned to develop strategies towards meeting the 2012 goal. Japan also produced an MPA database of East Asia and Micronesia in 2007 as a part of the ICRI Plan of Action 2005–2007 (available on [http://www.reefbase.org/key\\_topics/coralreefmpas.aspx](http://www.reefbase.org/key_topics/coralreefmpas.aspx)).

**Marine Protected Areas:** Most of China's 47 MPAs were established more than 20 years ago (only 10 have been created in the last 10 years), 16 of which contain coral reefs as the dominant habitat. The following major MPAs have been established: Sanya National Coral Reefs Nature Reserve, Hainan Province in 1990 (the most studied MPA in China); Dongshan Bay Provincial Coral Reef Nature Reserve in Fujian Province in 1998; Xuwen Large Yellow Croaker in 2000; Wailuohaiwan Bay's Limuloid Nature Reserve in 2001; Denglouliao Provincial Coral Reefs Nature Reserve, Guangdong Province in 2002, and Leizhou Liushawan Bay's Coral Reefs Nature Reserve in 2003. The upgraded Xuwen National Coral Reef Reserve, Guangdong Province was approved in April 2007. The Dongshan Coral Reserve (Fujian Province) is currently being upgraded.

There are 21 MPAs in Hong Kong, but only 2 contain coral reefs as the dominant habitat. Most of these MPAs are well-established, having been implemented over 20 years ago and managed by the Agriculture, Fisheries and Conservation Department. MPAs in Hong Kong are administered and managed at the national and country level to provide some protection for reef fish; however, they are not completely no-take zones as local inhabitants are still allowed to fish with non-destructive gear under a licensing system. No pre-protection data on fish diversity and abundance are available, thus the benefits of MPA designation are difficult to assess.

Most reef areas in Taiwan were already designated within national parks or national scenic areas; however, management was ineffective with inadequate laws and enforcement. Monitoring has revealed that most coral reefs are deteriorating, and possibly undergoing a phase shift from coral-dominated to algae-dominated communities. Fortunately, awareness is increasing the need for reef protection to sustain their marine resources. New holistic approaches to conservation and ecosystem-based management are being implemented to increase the resilience of the reefs in the face of climate change. Protection of the Dongsha Atoll was declared in 2004, and the Dongsha Marine National Park was established in 2006. Since then, the diversity of marine organisms has increased, including new species records. The Dongsha International Marine Research Station was commissioned to undertake comprehensive research on the diverse marine communities. This is the first national park in Taiwan with a theme of protecting the marine environment, covering all aspects of marine and terrestrial conservation, research, and environmental and ecological education. Coastal marine resources in Taiwan are declining, indicating that previous government regulations have not yielded effective results. Therefore a long-term ecosystem-based management plan integrating social, economical and ecological issues is being drafted for Kenting National Park, encompassing the next 25 years. The visions are to achieve sustainable fishery, well-managed protection of marine habitats, limited damage from human activities, and mitigation of the effects of climate change.

Japan has established 78 MPAs, 18 of which contain coral reefs as the dominant habitat. Most of these parks are well-established, having been implemented over 20 years ago, with only 4 established within the last decade. Administration is primarily at the national level (31 MPAs), although there are 24 MPAs managed at municipality level with the remaining MPAs managed at state/provincial level (11) and region/county level (8). The no-take area of Japanese MPAs was only 118.5 km<sup>2</sup>, or less than 1% of the total MPA area; this is likely to be a gross underestimation. The various measures to conserve the coral reefs in Japan are insufficient, especially the poor coordination in the conservation of adjacent land and sea areas. Environmental conservation is virtually ignored outside protected areas – development has priority over conservation. The ‘Coral Reef MPAs of East Asia and Micronesia’ database was a collaborative effort between The WorldFish Center (ReefBase Project) and Japan Wildlife Research Center (JWRC), and funded by the Ministry of the Environment, Japan, as part of the Japan-Palau ICRI Secretariat Plan of Action for 2005–2007. It contains information and GIS maps on MPAs in South-east, East and North Asia and Micronesia ([http://www.reefbase.org/key\\_topics/coralreefmpas.aspx](http://www.reefbase.org/key_topics/coralreefmpas.aspx)).

The southern part of Jeju-do in Korea was designated as a Natural Monument Protection Area by the Ministry of Maritime Affairs and Fisheries in 2001; the first MPA that includes corals and is also a Man in the Biosphere (MAB) Reserve Area within UNESCO. There are also 10 Wetland Protected Areas with the draft management plan, developed by the Korea Environment Institute, being reviewed for budget allocation. Many ministries with different names in Korea are involved (Natural Monument Protection Areas; Wetland Protection Area; Seogwipo City Marine Park; and MAB): these overlaps emphasize environmental conservation to the public, local stakeholders and local government as well as central government. The coral MPAs were designated recently and management plans are under progress or review. However, evaluation of management effectiveness has not been conducted. A ‘Hot Spot’ Program started in 2006 to select MPAs for corals and endemic species.

**Monitoring Capacity in East and North Asia:** The long-term monitoring program for Sanya National Coral Reef Natural Reserves in China in 2007 is based on the Survey Manual for Tropical Marine Resources and the Reef Check manual and has 26 sites for corals, 9 for reef fish and 9 sites for plankton in West Island of Sanya Bay, Xiaodonghai and Xipai of Yalong Bay. In addition a 2 year extensive survey project was made for other reefs in South China and Xisha Islands (Paracel Islands) in 2005 and 2006. All data will be stored on the Marine Development Planning and Design Academy of Hainan database and GIS system. The Chinese University of Hong Kong has conducted regular monitoring at 3 Marine Parks (Tung Ping Chau, Hoi Ha Wan and Yan Chau Tong) funded by the Agriculture, Fisheries and Conservation Department (AFCD), Hong Kong Special Administration Region (SAR). The Taiwanese Coral Reef Society has conducted regular monitoring since 1997, sponsored by the Administration of Fisheries of the Taiwanese government, with the first long-term project in Kenting National Park, southern Taiwan, to monitor coral reef changes since 2001. Japan started a national coral reef monitoring program in 2003, with 24 sites from Sekisei Lagoon northward to Tokyo Bay. Surveys are conducted by local scientists or NGO members with data stored in the database of Biodiversity Center of Japan, Ministry of the Environment. Reef Check is active and formed the Coral Network, Okinawa Reef Check and Research Group, Reef Check Kushimoto. A coral mapping program by the Ministry of the Environment has been using remote sensing to find hot spots of biodiversity since 2007: for example, WWF-Japan is surveying biodiversity at the south-west islands including Osumi, Tokara and Ryukyu islands to assist in management planning. Although no regular socioeconomic monitoring has been implemented in Japan, some surveys were conducted on Ishigaki Island to provide reliable data for management planning of Sekisei Lagoon. A regular monitoring program by the Ministry of Marine Affairs will report on management of Wetland Protected Areas in Korea, including coral monitoring for Jeju Island in 2008.

**Management Activities:** The 'Sanya-Biodiversity surveys, data management and monitoring, and related training' in China from 2006 to 2008 was supported by UNDP, GEF and SOA (State Ocean Administration) to generate data and analysis for policy decisions and to build capacity for long-term biodiversity surveys and data management. Taiwan plans to participate in the Integrated Coral Observing Network by establishing coral reef early warning systems to understand the impacts of climate change on coral reefs. The local association of dive operators in Japan has tried to eradicate COTS in specific areas and the outbreak seemed to end at Kerama Islands in 2007; however the outbreak in Sekisei Lagoon continued into 2007, despite efforts by the Ministry of the Environment. Local stakeholders have formed a local committee for integrated management of the Sekisei Lagoon with the Ministry; similarly Okinawa has a prefectural committee to improve coral conservation. The Korean Oceanology Research and Development Institute (KORDI) established a research station on Chuuk, Micronesia in 2000 for coral research and resource surveys.

**Reef Restoration:** Acknowledging that coral degradation is continuing, local managers have considered coral restoration as a quick solution. Coral relocation was attempted in Daya Bay, Guangdong Province, China, in September 2007 because an oil pipeline was being constructed. About 15 000 m<sup>2</sup> of coral communities were relocated 7 km to the east side of Guogaizhou Island, south of Chizhou Island, where water quality is better and monitoring is planned. In Taiwan coral reef restoration is being examined following strong demand. The Ministry of the Environment, Japan, has trialed reef restoration in Sekisei Lagoon and the Akajima Marine Science Laboratory has studied mass spawning at Kerama Islands for possible coral restoration.

Coral transplantation is a popular tourist attraction in Okinawa, organised by tourist operators and NGOs, and the Okinawa Prefectural Government is developing appropriate guidelines, similar to those produced by the Japan Coral Reef Society. Coral restoration research is still experimental with no proven success.

## CONCLUSIONS

Frequent bleaching and COTS outbreaks have been damaging to reefs of the region and slowed recovery after the mass bleaching in 1998. Land-based activities, over-fishing, destructive fishing, tourism, coastal development, sedimentation, sewage pollution, and global climate change are reducing coral resilience, further threatening these reefs. A possible phase shift from coral-dominated to algal-dominated reef communities is a concern in this region. Regular coral reef monitoring and research on corals occur in China, Hong Kong, Taiwan and Japan; Korea now recognizes an urgent need to implement monitoring. Socioeconomic monitoring has not been implemented to assist reef management. Integrated Coastal Zone Management is more focused in the region as an effective approach to conserve coral reefs and communities. All countries and states are planning to increase MPAs in number and efficiency; however, networks of effective MPAs have not been established. There is a high demand for reef restoration in China, Taiwan and Japan, and some commercial coral transplanting programs, with funding from companies, are operating in Japan to raise awareness: there is, however, no evidence of restoration success.

## RECOMMENDATIONS

- Increase the focus on socioeconomic monitoring as well as ecological monitoring to provide reliable data and information for better coastal management;
- Develop mechanisms for ensuring and extending the network of monitoring scientists to start a dialogue with managers and decision makers to recommend appropriate coral conservation;
- Implement programs of MPA enhancement in the region to identify gaps between the current situation and the WSSD 2012 goals;
- Improve coordination and cooperation within the region and between the regions of ENA and SEA as a wider regional initiative to share information and lessons learned;
- Conduct more research on reef restoration for reef managers to assess the effectiveness or otherwise of current methods.

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### THE CORAL REEFS OF EILAT, ISRAEL

The coral reefs of Eilat (northern Gulf of Eilat/Aqaba, Red Sea) are exposed to continual human pressures including water pollution, sedimentation, and recreational snorkel and scuba diving. Urban sewage and phosphate dust pollution have recently been reduced while groundwater inputs and port-ballast water contamination have increased. One major positive management step has been the complete cessation of sewage pollution from the city of Eilat since 1995. Another major corrective action was the cessation of fish farms of sea bream, *Sparus aurata*, that had been a major source of nutrient enrichment since 1991. The Government of Israel decided to close these farms in 2007–2008 based on extensive scientific data and recommendations (summarised in Status 2004 report). These increased nutrient concentrations were considered to be the main cause for the decline in the corals between 1986 and 2000. As a result of deep water mixing (increased nutrients were carried into surface water) in recent years (1995, 2007), the settlement and growth of macro-algae increased, but algal grazing fish reduced the algae and maintained the ecological balance of the reef. However, a negative sign is that more than 40 species of reef fish have been found to carry the exotic pathogen *Mycobacterium marinum*, introduced to the Gulf by the previous fish farm industry, including main grazing fish such as *Acanthurus nigrofuscus*, *Diplodus noct* and *Siganus rivulatus*. Five years of monitoring found that numbers of coral recruits were negatively correlated with algal biomass. The amount of healthy coral tissue decreased 2004–2006, while in 2007 more tissue looked healthy during the Israel National Monitoring Program at the northern Gulf of Aqaba. Concentrations of nutrients in the sediments is expected to decline in the future as there are no major human sources of nutrient pollution. There has been a recent increase in populations of crinoids (feather stars) on reefs which appears to be an indication of recovery. (from Noga Stambler, Bar Ilan University, Israel; David Zakai, Israel Nature and National Parks Protection Authority, Israel; Yonathan Shaked and Amatzia Genin).

# 11. STATUS OF THE CORAL REEFS IN AUSTRALIA AND PAPUA NEW GUINEA

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## ABSTRACT

- The corals reefs of Australia and Papua New Guinea cover 19% of the world's total reef area and contain levels of biological diversity approaching the 'hot spots' of the Philippines and Indonesia;
- Human pressures on these reefs are lower than in other parts of the world (particularly SE Asia). The reefs of eastern Australia, particularly the Great Barrier Reef (GBR), have a long history of research and monitoring and world leading management;
- Most coral reef management is implemented through Marine Protected Areas (MPAs) while fisheries resources are managed through specific fisheries management arrangements. Australian reefs are usually managed through cooperative arrangements between state and national governments, while management arrangements in PNG are predominantly driven by efforts of NGOs, local communities and local governments.

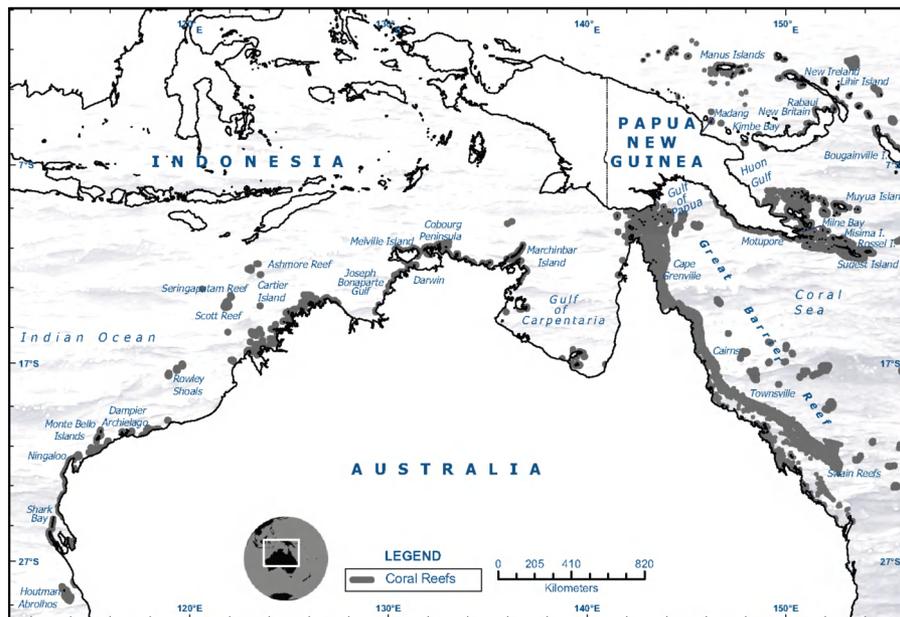
## *Eastern Australia*

- The oceanic and island reefs of the GBR and the Coral Sea are amongst the best understood and managed in the world with considerable capacity and expertise in research and management, particularly along the GBR;
- Rezoning of the GBR in 2004 was a major undertaking that is showing significant ecosystem benefits; new management plans are being developed for many Coral Sea islands and reefs;
- There is good information about many GBR reefs, and information is improving about Coral Sea reefs;

- The reefs remain in relatively good condition and the GBR may be in a recovery phase from previous disturbances indicating good resilience; many pressures remain and some Coral Sea reefs have not recovered from storms and bleaching in 2002;
- On-going pressures include coastal development, declining water quality, fishing, recreational use, outbreaks of crown-of-thorns starfish (COTS) and other species. Recent pressures include coral disease, declining resilience of some reefs (particularly inshore reefs), declines in high level predators, and climate change effects;
- The outlook for these reefs is generally good if pressures can be reduced and resilience to climate change maintained.

### Western Australia

- Western Australian reefs include extensive coastal reef systems and isolated and remote offshore oceanic reefs and islands;
- Most reefs are far from urban centres and are in relatively good condition. New management plans have been introduced and more are being developed;
- The rezoning of Ningaloo Marine Park in 2005 has increased no-take areas to 34%, helping to increase the resilience of this coral reef to pressures from climate change;
- Other pressures include fishing (recreational, commercial and illegal foreign fishing), major resource development (including ports), pollution, localised recreational use, coral bleaching, and outbreaks of the coral eating snail, *Drupella*;
- Research and monitoring has increased significantly, paralleled by increases in research capacity;
- The prognosis for these reefs is good provided reef resilience can be maintained against climate change damage.



## **Papua New Guinea**

- Papua New Guinea (PNG) has many coastal reefs and offshore patch reefs with high biodiversity;
- Information on PNG reefs is limited, with little research, monitoring and management capacity. Some monitoring data are available from independent sources;
- Many areas are remote, isolated and difficult to access and manage. However, this isolation has reduced the impact of human activities on reefs;
- Pressures include terrestrial sedimentation from poor land management, over-fishing (particularly of invertebrates such as sea cucumbers), loss of top level predators in some areas, destructive fishing, COTS outbreaks and coral bleaching;
- PNG reefs are likely to be affected by global climate change, thus local stresses should be addressed to maintain reef resilience against climate change threats.

## **STATUS OF CORAL REEFS, MANGROVES AND SEAGRASSES IN 2008**

The reefs of eastern Australia include the Great Barrier Reef (GBR), oceanic reefs in the Coral Sea, Lord Howe Island, and transient coastal coral reefs in the Solitary Islands.

**Great Barrier Reef:** The GBR covers approximately 350 000 km<sup>2</sup> including 2000 individual reefs along the east coast of Queensland. It was officially protected in 1975 with the establishment of the Great Barrier Reef Marine Park (GBRMP) and declared a World Heritage Area in 1981. The GBRMP was rezoned in 2004 to include 33% of the area as no-take 'green' zones to protect ecosystem resilience and provide ecological 'insurance' against increasing pressures. The GBR has considerable research and management infrastructure such as the Great Barrier Reef Marine Park Authority, the Australian Institute of Marine Science (AIMS), universities (particularly James Cook University and the University of Queensland), the Marine and Tropical Science Research Facility and the Queensland Environmental Protection Agency. The GBRMP is primarily managed through marine park zoning that allows different uses to occur in different areas. Fishing is regulated through fisheries management arrangements overseen by the Queensland Department of Primary Industries and Fisheries.

There is a long history of research and monitoring on the GBR, ranging from major, inter-agency research programs to many small independent research projects. The AIMS Long-term Monitoring Program has conducted annual manta-tow monitoring since 1986, with more intensive scuba surveys of coral reef benthos and fish at fixed sites since 1993. The program was altered in 2006 to monitor the effects of GBRMP rezoning with reef monitoring now conducted every two years.

Coral cover on the GBR is greatly affected by disturbances such as cyclones and outbreaks of COTS (*Acanthaster planci*) and, to a lesser extent, by coral bleaching and disease. The GBR appears to be in a period of recovery and growth; COTS activity has declined following the third recorded 'wave' of COTS outbreaks. In 2006–2007 only 4–6% of reefs surveyed showed significant COTS activity and no COTS activity was recorded on the Swains reefs in the southern GBR; the first time the Swains reefs have not had COTS activity since the mid 1980s.

Hard coral cover has increased in the Cairns, Whitsundays and Swains regions of the GBR with the highest cover being in the Capricorn-Bunker (55%) and the Whitsunday (46%) sectors.

Coral cover was lowest on mid-shelf reefs in the Townsville sector which is recovering from COTS outbreaks. Coral cover on outer-shelf reefs in the northern GBR has declined by 50% in the last two years from very high levels recorded in 2000. This decline is attributed to storm damage and coral disease.

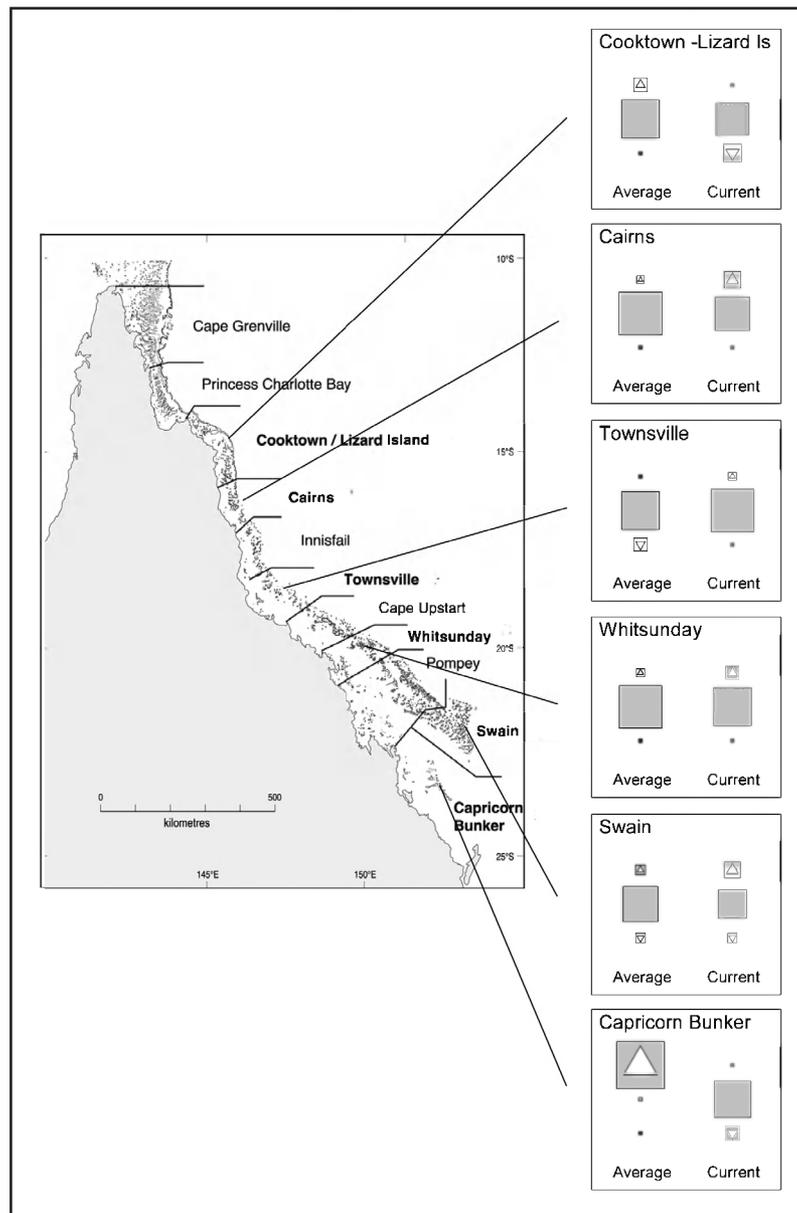
The increase in no-take reserves in the GBRMP has resulted in positive ecological flow-on effects. The biomass and density of target fish species has significantly increased in the 4 years since the new zoning was introduced (Box p. 164), and COTS outbreaks appear to be significantly reduced within no-take reserves (Box p. 162), suggesting that there are ecological processes operating within no-take reserves that are not fully functional elsewhere.

Although the GBR is in relatively good condition and has world best practice management, it faces on-going challenges. Many components of the GBR ecosystem may be highly vulnerable to climate change including increasing evidence of the emerging threats of ocean acidification. The resilience of the GBR may be reduced by human pressures: declining water quality is already affecting some inshore coral reefs with observed changes in community composition and density and diversity of juvenile corals on some reefs. There is also emerging evidence that community composition on inshore reefs has significantly changed since European settlement started 200 years ago. Extractive activities such as fishing may alter ecological processes and trophic pathways (Box p.162); and the density of top predators such as reef sharks appears to have been significantly reduced on some reefs. While the GBR coastal population is small compared to other areas, it is rapidly increasing and bringing greater pressures for development and use of the GBRMP.

#### **NO-TAKE MARINE RESERVES REDUCE COTS OUTBREAKS**

It has been suggested that human activities such as nutrient enrichment of coastal waters through terrestrial runoff, and the removal of predators through fishing, may influence outbreaks of COTS. Extensive surveys of the GBRMP over a 10 year period of active COTS outbreaks occurring after no-take reserves were fully implemented (1994–2004) showed that the relative frequency of COTS outbreaks was 3.75 times higher on 'open' reefs compared to reefs zoned as 'no-take' marine reserves. While these data are clear, there is no obvious explanation for these differences. The main target species (groupers and snappers) extracted from the 'open' reefs surveyed are not considered to feed on COTS. This suggests that no-take marine reserves preserve some ecological links or a trophic pathway that indirectly control COTS numbers.

There are approximately 3800 km<sup>2</sup> of mangrove and saltmarsh habitat along the GBR coast, with this area remaining relatively stable. However these mangrove forests are only remnants of more extensive forests that have been progressively cleared since European settlement started 200 years ago. Some localised losses of mangroves have occurred and the main pressures are from continued coastal development.



*Summaries of trends in hard coral cover along the length of the GBR, 1993–2007. Each section of the GBR is represented by two sets of squares. The dimensions of each square represent the proportion of reefs showing an increase (top square), no change (middle square) or decrease (bottom square) in coral cover. Arrow heads show whether a change is an increase or decrease. The left hand box plots show average trends over the last 15 years, right hand box plots show current trends (from 2006–2007), for example, the majority of reefs in the Capricorn Bunker section have had increasing coral cover over the last 15 years. In 2006–2007, coral cover stayed the same on most reefs, declined on some reefs and increased on a few reefs.*

GBR seagrasses are highly variable and are particularly affected by storms and floods. There are approximately 46 000 km<sup>2</sup> of deep and shallow seagrass beds with no apparent widespread declines, although there have been localised losses. Seagrasses are affected by declining water quality, coastal development and localised impacts.

Further information: The AIMS Long-term monitoring program:

- <http://www.aims.gov.au/docs/research/monitoring/reef/reef-monitoring.html>

Science and research on the GBR:

- [http://www.gbrmpa.gov.au/corp\\_site/info\\_services/science\\_management](http://www.gbrmpa.gov.au/corp_site/info_services/science_management)
- <http://www.rrrc.org.au/>

### ECOLOGICAL EFFECTS OF THE REZONING OF THE GBR MARINE PARK

The inshore coral reefs of the GBR Marine Park predominantly fringe continental islands. Due to their proximity to population centres, these inshore reefs are frequently visited and subject to significant levels of recreational fishing pressure. High levels of compliance and relatively effective surveillance and enforcement also mean that these inshore reefs are some of the best protected within the GBRMP. Monitoring of fish populations using underwater visual census (UVC) was initiated in 1999–2000 to assess the effectiveness of zoning protection since late 1980s on reefs of the Palm, Whitsunday and Keppel islands. Published results focused on the major target of GBR hook and line fisheries, the coral trout (a grouper, *Plectropomus* spp.): after 12–14 years of protection, coral trout biomass had increased 3–6 fold within no-take marine reserves while there were no increases in surrounding fished areas. The GBRMP zoning plan was updated in July 2004 and the area of no-take marine reserve was increased from 4.5% to 33.4%. New studies revealed that after only 1.5 to 2 years of no-take protection, the coral trout density had increased significantly in newly protected areas (by about 65% in 2 island groups), but there were no significant changes in areas open to fishing. These early results provide an encouraging message that bold political steps to protect marine biodiversity can produce rapid positive results for exploited species.

**Coral Sea Reefs and Islands:** These reefs grow around oceanic islands and seamounts scattered across 780 000 km<sup>2</sup> of ocean east of the GBR. Some remote reefs are visited by tourism operators (for example, Osprey Reef, Flinders Reef) but most are rarely visited. There are several MPAs on Coral Sea islands and reefs, including the Coringa-Herald, Lihou Reef, Elizabeth and Middleton Reef reserves, and Lord Howe Island. The Elizabeth and Middleton reefs and Lord Howe Island are the most southerly coral reefs in the world and are strongly influenced by the south flowing East Australian Current. There has been limited research and monitoring apart from occasional surveys by AIMS and JCU for the Department of the Environment, Water, Heritage and the Arts (DEWHA). Climate change is probably the main pressure on these reefs.

**Osprey Reef** is an oceanic seamount 340 km NNE from Cairns and 180 km off the coast. This reef is frequently visited by divers from Cairns and Port Douglas and has been monitored by Reef Check Australia volunteers since 2002. Hard coral was damaged by coral bleaching in 2002 but appears to have recovered. Coral cover remains at about 40% at two sites with one site showing a slight decrease since 2004. An unofficial agreement has been reached between fishers and the tourism industry to protect high value tourism sites from fishing impacts. Further information on Osprey Reef from Reef Check Australia:

- <http://www.reefcheckaustralia.org/publications/2008%20Site%20Report%20finalsm.pdf>

The **Coringa-Herald Nature Reserve** is 400 km directly east of Cairns and covers 8856 km<sup>2</sup> including 6 islets and cays with a total area of 124 ha. AIMS surveys showed low coral cover compared to the GBR, with 4.5% cover recorded in 2003 and 7.3% in 2006–2007. There is evidence of significant coral mortality following coral bleaching in 2002 and physical damage from storms. Recovery appears to be slow and is probably dependent on self-seeding, making these reefs vulnerable to localised extinctions. The fish assemblages are very different to the GBR and indicate that these reefs may be 'stepping stones' between the GBR and the South Pacific. Some holothurians (sea cucumbers) of high commercial value were found to be more abundant within the reserve compared with other sites, suggesting some benefit of the reserve for these species. In 2005 beneficial insects were released at Coringa-Herald to minimise damage to the *Pisonia* forest from pest insects.

The **Lihou Reef Nature Reserve** is 700 km due east of Cairns and includes 18 coral cays covering 91 ha dotted around Lihou Reef, a U-shaped line of reefs facing west-south-west and enclosing a lagoon. No new surveys have been conducted at Lihou Reef since the previous *Status of Coral Reefs of the World: 2004*, when coral cover in 1984 and 2004 was low (<10%) with many corals bleaching due to elevated sea surface temperatures at the time of the 2004 survey. There was also evidence of bleaching from the 2002 bleaching event.

The **Elizabeth and Middleton Reefs Reserve** covers 1880 km<sup>2</sup> and the reefs are part of the Lord Howe volcanic chain. Surveys in February 2006 found that coral cover was similar to 2003 levels: 25% at Elizabeth Reef; and 11% at Middleton Reef. There was no evidence of recent bleaching or *Drupella* activity and only limited evidence of COTS. Surveys of fishes have recorded 324 species with two additional goby species identified in 2007. Genetic studies on the Galapagos sharks suggest that the Elizabeth and Middleton Reef population forms a single stock that is distinct from the Lord Howe Island population. In 2006 the Australian Government introduced a 7 year management plan for the reserve and has since increased compliance and enforcement patrols.

**Lord Howe Island** is 700 km north-east of Sydney and was listed as a World Heritage Area in 1982. The reefs around Lord Howe Island have a unique mix of tropical and temperate species with 83 coral species, 500 fish species and more than 300 species of macro-algae. Surveys in 2006 and 2008 found that coral communities were generally in good condition with 22% coral cover in 2006 and 19.3% in 2008. The most striking change between 2006 and 2008 was the increasing prominence of the 'lamington' urchin, *Triploneustes gratilla*. Abundance of *Triploneustes* increased dramatically from 2.4% of total invertebrate abundance in 2006 to 27% in 2008. The greatest increase was at sites in the Admiralty Islands where a massive outbreak

occurred, averaging > 270 individuals per site (200 m<sup>2</sup> survey area) in 2008. The *Tripneustes* population outbreak has significantly altered the bottom community with reductions of iconic macro-algae species, such that commercial dive operators have reported reduced aesthetic value at these sites. While flow-on effects to the broader community are not yet evident, the *Tripneustes* outbreak represents a potential threat to Lord Howe Island reefs. Lord Howe Island and its surrounding waters are designated MPAs, managed by the New South Wales and Australian Governments. The MPAs include significant 'no-take' zones to protect representative habitats from human influences. Further information about Lord Howe Island at:

- <http://www.mpa.nsw.gov.au/lhimp.html>
- <http://www.environment.gov.au/coasts/mpa/lordhowe/index.html>

More information on Coringa-Herald, Lihou, Elizabeth, Middleton and Lord Howe Island at:

- <http://www.environment.gov.au/coasts/mpa/publications/index.html>

The **Solitary Islands** are 600 km north of Sydney on the northern coast of New South Wales (NSW). The corals grow on a rock basement and are transient, such that they do not form carbonate reef structures. More than 90 hard coral and 530 fish species have been recorded and include a mix of tropical and sub-tropical species. Coral communities are dominated by *Turbinaria* spp., tabulate and corymbose *Acropora* spp., *Pocillopora* spp. and *Goniastrea* spp. The NSW Marine Parks Authority has surveyed the Solitary Island reefs every 2 years since 2000. Coral cover between sites varies between 15% and 50%. From 2002–2006 average coral cover combined for all sites has remained stable at about 30%. Low levels of coral bleaching were observed between 2000 and 2007, but the Solitary Islands did not experience the mass coral bleaching observed elsewhere in Australia in 2002. Some corals have been affected by a 'white syndrome' disease with 10% mortality of tagged corals; research is on-going. The Solitary Islands and surrounding waters are zoned as MPAs, managed by the NSW and Australian Governments. The Solitary Islands Marine Park was rezoned in 2002 and initial results show that some fishes are showing positive trends within sanctuary zones. More information about the Solitary Islands at:

- <http://www.mpa.nsw.gov.au/simp.html>
- <http://www.environment.gov.au/coasts/mpa/solitary/index.html>

## **Western Australia**

Western Australia (WA) has rich marine biodiversity that is ranked second in the world in terms of its endemism. WA's coral reefs are diverse and include the Houtman Abrolhos Islands as the most southerly reefs in the Indian Ocean, Ningaloo Reef as the longest fringing reef in the world (280 km), and emergent oceanic reefs and islands such as Ashmore and Scott reefs. WA contains 44% of Australia's coastline and the coastal areas between Carnarvon and the Northern Territory contain large areas of coral reef. Most reefs are far from population centres and are often close to the coast. There is minimal terrestrial runoff as much of the adjacent coast is dry and arid. Marine Parks in WA are managed and monitored by the Western Australian Department of Conservation (DEC, formerly the Department of Conservation and Land Management) and the Federal Government DEWHA, apart from the Houtman-Abrolhos Islands which are managed by the WA Department of Fisheries.

Research and management effort in WA is rapidly increasing, including new management plans for Ningaloo Reef (2005), Ashmore Reef (2002), Cartier Reef (2002), the Rowley Shoals

(2007) and the Montebello/Barrow Islands (2007). Three new marine parks are likely to be declared in the near future and regional marine planning is underway. The launch of the new Western Australian Marine Science Institution (WAMSI) in May 2007, a collaborative research initiative between Commonwealth research organisations, State government departments, WA universities and the private sector, has significantly increased WA's marine research and monitoring capacity and will help to underpin management of its marine resources. An increase in knowledge of the extensive fringing coral reefs of the Kimberley suggests these reefs are of international significance and a major research program for the region is being developed.

The vast distances and the isolation of many reefs pose significant challenges for research, monitoring and management. More information about WA reefs can be found at:

- <http://www.dec.wa.gov.au/park-finder/property/marine-parks-and-reserves/ningaloo-marine-park.html>
- <http://www.environment.gov.au/coasts/mpa/index.html>
- <http://www.wamsi.org.au>

The **Ashmore and Cartier Island** reefs lie in the Timor Sea between WA and Indonesia. Ashmore is 840 km west of Darwin, in more than 100 m depth, forming a shelf-edge coral atoll. The Ashmore Reef National Nature Reserve includes 3 islands, a large reef shelf and the surrounding waters. Cartier Island lies 46 km southeast of Ashmore and together the 2 reserves cover 750 km<sup>2</sup>. Scott, Ashmore and Cartier reefs were severely bleached in 1998 with more than 80% declines in coral cover to 30 m depth. Subsequent bleaching in 2003 caused a further 15% decline in coral cover at some sites. By 2005 live coral cover had declined to 10% at Ashmore and 16% at Cartier with very few coral recruits. Coral diversity may have decreased following the bleaching but fish communities remain diverse and abundant. Some high-value sea cucumbers are absent and may have become locally extinct due to over-exploitation. Indonesian fishers have historically fished Ashmore and Cartier heavily, especially harvesting sea cucumbers, trochus and shark fin. The 2002 management plan banned fishing in the reserve and has seen effective enforcement. In 2008 an Australian customs vessel was deployed to Ashmore Reef as a near permanent police presence.

The **Rowley Shoals** lie 300 km north-west of Broome and include Mermaid, Clerke and Imperieuse reefs. All three reefs are MPAs and are cooperatively managed by the Australian and WA Governments. There are more than 233 species of hard coral growing in clear waters down to great depths and 528 fish species have been recorded. Mermaid Reef is managed by the Australian Government and a new management plan will include installing moorings to reduce anchoring damage. Surveys in 2006 and 2007 added 23 new coral species as well as 43 echinoderms and 373 molluscs. The WA Government released a new management plan for Clerke and Imperieuse reefs in 2007 that extended the park to 87 632 ha, of which 24% are no-take 'sanctuary zones'. Imperieuse Reef suffered significant cyclone damage in 1995 that reduced coral cover from 60% to 10% but the reef has made a rapid recovery. Due to their isolation and protection from most human impacts, the Rowley Shoals are amongst the most pristine coral reef environments remaining in the world and, apart from some targeted reef fish species, the coral reefs of the Rowley Shoals appear to be in good condition.

The **Dampier Archipelago** contains coral communities that are subject to many human stresses. The mining towns of Dampier and Karratha have the highest per capita boat ownership in WA

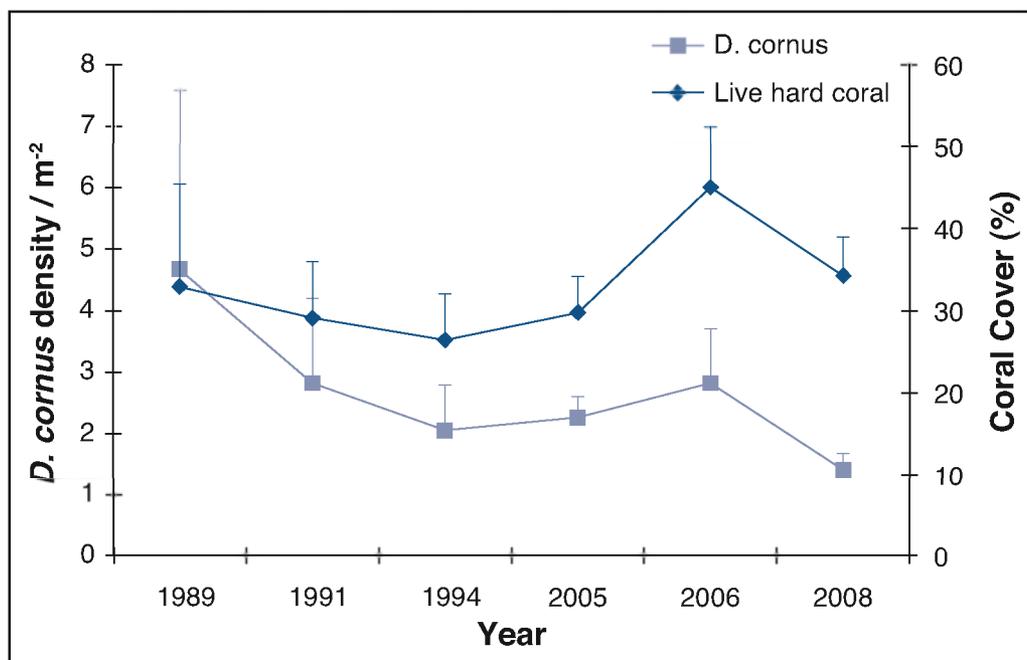
along with rapid industrialisation, including a major dredging project in Dampier Harbour. The corals are also subject to extremely variable environmental conditions including macro-tides, cyclones and storm events, high and/or extremely variable turbidity, and warming seawater temperatures. There are a broad range of coral habitats in the Dampier Archipelago that support the second most diverse coral fauna in WA. A marine park is proposed for the Dampier Archipelago and the planning process is nearing completion. DEC surveyed 12 sites across the Archipelago in September 2008 as a precursor to a long term monitoring program for the proposed marine park. The dominant coral forms are corymbose and plate *Acropora* spp., with significant numbers of poritid, favid and mussid corals. *Drupella* and COTS were rarely encountered during the survey.

The **Monte-bello and Barrow Islands** lie off the Pilbara coast in north-west WA, 1600 km north of Perth. The islands form a complex archipelago of 265 low lying islands and islets in an area of 2100 km<sup>2</sup> containing mainly tropical flora and fauna. The Montebello/Barrow Islands MPAs were established in 2005 with a new management plan introduced in 2007. These coral reefs may be a source of larval recruits for coral reefs further south such as the Pilbara inshore islands, Muiron Islands and Ningaloo reef. DEC is establishing a long-term monitoring program and initial surveys in August 2006 established 26 potential sites. Live hard coral cover ranged from 2–58% at 19 sites, and from 37–62% at 7 patch reefs. Mean cover of macro-algae was low (<6%) while turf algae were more abundant (27–67%). The abundance of COTS and *Drupella* was low.

**Ningaloo Reef** is the longest fringing reef in the world (280 km) and is 1000 km north of Perth where temperate and tropical currents converge in the Ningaloo region. This has resulted in high coral reef diversity with more than 500 fish, 250 coral and 600 mollusc species. Ningaloo Marine Park (which includes State and Commonwealth waters) was established in 1987 and the State waters of the marine park were extended in 2004 along with the inclusion of the Muiron Islands Marine Management Area. Combined, the marine reserves cover 5355 km<sup>2</sup> and are managed by the WA and Australian Governments. The WA Government released a new management plan for the State section in 2005 with increases in the area of 'sanctuary zones' to 34% of the park area. DEC are implementing a long-term monitoring program that will help improve the science underpinning the management of Ningaloo Marine Park.

The first major coral bleaching event recorded at Ningaloo Reef occurred during winter in 2006. An unusual combination of low spring tides, a high pressure system and cold air temperatures resulted in the bleaching of shallow water corals. However, almost full recovery has occurred.

Between the mid-1980s and 1990s Ningaloo Reef was severely damaged by outbreaks of the coral eating snail, *Drupella cornus*, with coral mortality approaching 100% in some locations. DEC surveyed *Drupella* density and benthic reef communities (including coral cover) in 1987, 1989, 1991, 1994, 2005, 2006 and 2008, with future surveys to be conducted every 3 years. Currently, coral cover varies between 30% and 60% and *Drupella* and COTS densities are low to moderate. Coral communities are healthy and dominated by *Acropora* spp. at most sites. Overall, coral communities appear to have recovered from the *Drupella* damage in the 1980s with coral cover increasing consistently at most locations. Ningaloo Reef faces pressures from storms and cyclones, pollution, local fishing and recreational use (such as anchor damage), coastal development and introduced species (such as foxes that take newly hatched turtles).



**The overall trends in *Drupella cornus* density at Ningaloo Marine Park 1989-2008 show similar trends to live hard coral cover (data show means of all locations with standard error).**

**Macro-algae, seagrasses and mangroves:** The Ningaloo Marine Park includes 2200 ha of macro-algal meadows. The dominant genera are *Sargassum*, *Padina*, *Dictyota* and *Hydroclathrus*. Seagrasses are patchily distributed within the reserves and are not a major component or major primary producer. While no comprehensive surveys of macro-algae or seagrasses have been completed, the region is currently the focus of marine flora studies. Mangroves comprise about 0.1% (33 ha) of the area of the Marine Park, and the mangroves, seagrasses and macro-algae appear to be relatively healthy.

Research and monitoring in the Ningaloo Marine Park is rapidly increasing with the initiation of the Ningaloo Research Program (NRP) associated with the release of the 2005 Ningaloo Marine Park Management Plan. The program has grown to approximately \$30 million dollars of research over 4 years with co-investment and collaboration of research organisations and universities through WAMSI and through the CSIRO Wealth from Oceans National Research Flagship and the Ningaloo Collaboration Cluster. More information about the Ningaloo Research Program and its key elements:

- [www.ningaloo.org.au](http://www.ningaloo.org.au)
- [www.wamsi.org.au](http://www.wamsi.org.au)
- [www.csiro.au/science/Ningaloo](http://www.csiro.au/science/Ningaloo)

The **Houtman Abrolhos Islands** consist of 122 islands 60 km off Geraldton on the mid-west coast of WA. These islands are the most southerly coral reefs in the Indian Ocean and support a mix of tropical and temperate fauna including 389 species of fish and more than 50 coral

genera. The islands are important habitats for seabirds and sea lions, and are crucial to the WA rock lobster (crayfish) fishery with up to 50% of the western lobster spawning output coming from the area. The islands are managed by the WA Department of Fisheries and management arrangements are currently being reviewed. The islands are zoned as a Fish Habitat Protection Area (253 100 ha) that currently includes 4 'Reef Observation Areas' (6859 ha) that exclude extractive activities except for licensed lobster trap fishing. Between 1995 and 2002, coral trout numbers increased between 3 and 7 times within the closed areas but there was no clear pattern for wrasses. There are no existing coral reef monitoring programs, however, the Abrolhos Island Research Institute was established in 2006 and is likely to increase research activity. Baldchin grouper (a wrasse) are under pressure in the Houtman Abrolhos Islands and an interim ban on the take of baldchin grouper was introduced in 2008. More information on the Houtman Abrolhos Islands can be found at:

- <http://www.fish.wa.gov.au/sec/env/west/index.php?0502>

### ***Papua New Guinea***

The coral reefs of the north and east coast of Papua New Guinea (PNG) lie within the 'coral triangle' that includes eastern Indonesia, the Philippines, Timor Leste and the Solomon Islands. The coral triangle is a global centre of marine biodiversity and has very high conservation value. Many reefs in PNG are close to shore and sensitive to terrestrial influences. Research and monitoring capacity in PNG is relatively low with most programs run by NGOs; such that there are few long term datasets for PNG reefs. There are also few MPAs in PNG and awareness and support for marine resource management is mostly limited to areas where NGOs have active programs such as in Kimbe Bay, Kavieng, Manus and Madang. A system of customary tenure ('tambu') for fringing reefs and inshore fishing resources exists in many coastal communities. Temporary closing of a reef is a historical practice that is now declining. Most reefs in PNG are in relatively good condition, although some reefs are under pressure from: sedimentation arising from poor management of mining, land clearing, oil-palm plantations and logging; over-fishing, including top predators such as sharks and invertebrates such as sea cucumbers (bêche-de-mer); the live fish trade; COTS outbreaks; and coral bleaching.

The **New Britain Province (East and West)** is a large area that includes the well studied Kimbe Bay region being monitored by The Nature Conservancy (TNC). At least 860 fish and 400 hard coral species have been recorded from Kimbe Bay. Annual reef monitoring by James Cook University (JCU) and TNC began in 1996. Coral cover on the coastal fringing reefs declined from ~70% to ~7% between 1996 and 2003, but has recovered considerably in the last 5 years. Cover of all major coral families has increased, including acroporids, pocilloporids and poritids, with total branching coral cover peaking at 26% in 2007. Likewise, declines in coral reef fish biodiversity between 1997 and 2002 have been followed by almost full recovery of most affected reef fish species between 2002 and 2007. However, severe localised bleaching was recorded at surveyed reefs in early 2008, and macro-algal cover and the amount of unconsolidated sediments have increased gradually over the last 10 years.

Four marine reserves were established in 1999 and changes in coral and fish assemblages in Kimbe Bay are almost identical across all 4 areas. The marine reserves have resulted in increases in the abundance of a few reef fishes, most notably the surgeonfish (Acanthuridae). Since 2006 TNC have been developing an MPA network for Kimbe Bay that incorporates the principles of reef resilience and connectivity as well as social and economic factors. They are

working with local communities and governments, with the support of local NGOs (Mahonia Na Dari), to establish 'community protection areas' or Locally Managed Marine Areas (LMMAs), and to address land use and management issues. The Kimbe Bay wide system of MPAs is likely to deliver major benefits to the region. Researchers from JCU have shown that fish larvae in Kimbe Bay are retained within a single MPA and also transported to adjacent MPAs, demonstrating wide-spread larval connectivity within the MPA network.

There has been little other coral reef research in the rest of East New Britain province since the *Status of coral reefs of the World: 2004* report. Information about research and management in Kimbe Bay can be found at:

- <http://www.nature.org/wherework/asiapacific/papuanewguinea/work/art6726.html>;
- [http://www.lmmanetwork.org/Site\\_Page.cfm?PageID=42](http://www.lmmanetwork.org/Site_Page.cfm?PageID=42)

The **New Ireland Province** includes diverse fringing coral reef, lagoonal and mangrove systems. The Wildlife Conservation Society (WCS) PNG Marine Program monitors 3 'tambu' sites established in 2006 and are establishing new tambu areas with partner communities, which also participate in monitoring 6 areas through the PNG LMMA Network. From 2006–2008 data were collected at 6 sites: Ungakum (no-take) and Kavulik (open to fishing) in the Tsoi Islands of the archipelago; and Lasigi (no-take), Malom (open), Silom (notake) and Dabanot (open) on the north-eastern central coast of the main island. In 2008 mean coral cover in the Tsoi islands was 19%, a significant drop from 41% in 2007. Coral cover at the main island sites in 2007 ranged between 24% and 30%, and 2008 results for Malom are 23%. Macro-algal cover increased at all sites from 52% in 2006 to 59% in 2007, and further increased to 72% at 3 of the 6 sites in 2008. Average coral cover at all sites dropped from 40% in 2006 to 30% in 2007, and declined again to 20% at 3 of 6 sites in 2008. The greatest change between 2006 and 2007 was at the central main island sites, Lasigi and Malom, where coral cover decreased by as much as 23% and macro-algal cover increased by 17%; possibly due to impacts from extensive oil palm plantations and COTS outbreaks. There has been minimal coral disease and some coral bleaching, but some 'tambu' areas have been affected by COTS. Damaged areas represent a mean of 0.1% of total area, which is significant considering that hard coral cover is as low as 8% at some sites. COTS damage variation between sites is high.

| New Ireland Province Monitoring Sites | Bleaching (m <sup>2</sup> /ha.) | <i>A. planci</i> predation (m <sup>2</sup> /ha.) | <i>Drupella</i> sp. predation (m <sup>2</sup> /ha.) | Black band disease (m <sup>2</sup> /ha.) | White band disease (m <sup>2</sup> /ha.) |
|---------------------------------------|---------------------------------|--|---|--|--|
| Managed areas (Tambu)                 | 175.4<br>(SD 192.3)             | 5398<br>(SD 9595)                                | 111.1<br>(SD 235.9)                                 | Not seen                                 | 333<br>(SD 748)                          |
| Areas open to fishing                 | 209.5<br>(SD 238.5)             | 727<br>(SD 983)                                  | 50.6<br>(SD 61.4)                                   | Not seen                                 | 260<br>(SD 171.5)                        |

*This table summarises coral damage recorded by WCS in September and October 2007 at protected and nearby unprotected sites in New Ireland. No clear pattern has emerged in these indicators of damage on the 12 transects each 50 m by 2 m at 4 m and 7 m depth. Values are means with standard deviation (SD).*

Reefs in New Ireland support relatively healthy populations of rarer fish such as bumphead parrotfish (*Bolbometopon muricatum*), humphead wrasse (*Cheilinus undulates*) and reef sharks; however commercial fishing pressures are increasing to supply a fish processing plant in Kavieng. Pressure on sea cucumbers is also increasing with PNG National Fisheries Authority surveys in 2006 showing stock collapses at several sites. The implementation of LMMA 'no-take' areas by the communities has shown rapid and positive results: after one year, mean fish biomass increased from 239 kg/ha to 303 kg/ha at the managed no-take sites while there was no significant change at the fished 'open' sites. The greatest change in biomass was recorded in piscivores at shallow sites, with a significant increase of 3.83 kg/ha at managed sites compared to a decrease of 2.43 kg/ha recorded at 'open' sites. These trends were strongest in both density and biomass of the trout and groupers (Serranidae) and snappers (Lutjanidae). Support for the reintroduction of customary management techniques has grown since 2006 within the Province, with more communities planning on re-introducing tambu areas. However, there is low capacity to support such community initiatives, at village, government and NGO levels. Some New Ireland Local Level Governments are developing laws to recognise community based fisheries management areas. More information about New Ireland:

- <http://www.wcs.org/globalconservation/marine/46886020>;
- [http://www.lmmanetwork.org/Site\\_Page.cfm?PageID=42](http://www.lmmanetwork.org/Site_Page.cfm?PageID=42)

**Manus Province:** The WCS is monitoring sites at Andra and Ahus islands 5 km off the north coast of Manus Island. Total coral cover is about 25% at Andra Island and 24% at Ahus Island, slight decreases from the 30% reported in the *Status of the Coral Reefs of the World: 2004*. Algal cover is approximately 43–44% at Andra and Ahus islands respectively. Fish biomass is relatively high at both islands (Andra 332 kg/ha, Ahus 346 kg/ha) compared to other sites in PNG.

| Manus Site | Total fish Biomass (kg/ha) |          | Hard Coral Cover (%)           |         | Algal Cover (%)        |         |
|------------|----------------------------|----------|--------------------------------|---------|------------------------|---------|
|            | Andra                      | 331.6    | SD 124.9                       | 24.5    | SD 9.8                 | 43.8    |
| Ahus       | 345.6                      | SD 178.0 | 23.9                           | SD 8.7  | 44.6                   | SD 12.6 |
|            | COTS Abundance             |          | <i>Tridacna</i> spp. Abundance |         | Sea Cucumber Abundance |         |
| Andra      | 0.17                       | SD 0.39  | 1.08                           | SD 1.16 | 8.00                   | SD 8.6  |
| Ahus       | 0.08                       | SD 0.29  | 0.42                           | SD 0.51 | 0.42                   | SD 0.7  |

*These ecological data from Andra and Ahus Island, Manus Province from Sept–Oct 2007 show relatively healthy coral and fish populations but low abundance of target species such as giant clams (*Tridacna*) and sea cucumbers, COTS populations are also low. Fish biomass by underwater visual census on belt transects; percent cover by point intercept transects; data <4m depth. Values are means with standard deviation (SD).*

Manus has the smallest land area and population of any PNG province with about 500 people on Andra Island and 900 on Ahus Island. The Andra community has a customary monopoly to supply local and provincial capital markets with lime from scleractinian corals to chew with betelnut. Whilst this has reduced their reliance on other marine products, most noticeably

*Tridacna* spp., clams and sea cucumber, the *Acropora* cover on Andra is low compared to Ahus (5.4% compared to 10.6%). The locals on Andra Island perceive that the condition of marine resources has declined over the past 5 years and will continue to decline for the next 5 years.

### IMPRESSIONS OF PNG REEFS AFTER 33 YEARS OF DIVING

Coral reefs are not monuments, but are very dynamic. I witnessed a COTS invasion of the reefs around Milne Bay in the early 1980s that wiped out almost all of the hard corals but within 5 years the reef had regenerated. These are now 'old' reefs with very large plate and other corals that are breaking, simply because of their large size. In 2008 there is a moderate outbreak of COTS on some reefs again. I also witnessed massive coral bleaching with large scale mortality (1996 and 1998); there have been no serious bleaching events since. The bleaching in both instances followed a change in current direction, from the north bringing warmer water. My principal observation is that recovery of coral reefs is swift if water quality is good. I have also observed and photographed a vibrant, healthy (almost exuberant!) coral reef where volcanic CO<sub>2</sub> bubbles to the surface. It is interesting that those corals tolerate the presumably acidic conditions, although water pH was not measured. There is also a healthy seagrass bed, and barren areas where the vents and sea floor are hot. In Port Moresby where a sewage outfall was built into the lagoon, rapid and chronic deterioration of the reefs occurred. Reefs that have suffered trauma through dynamite or ship grounding appear to take much longer to recover. In my view, the biggest degradation of reefs is due to kilometres of long lines strung over them and over-fishing of sharks, whose populations have very obviously fallen dramatically! Another area of concern to me is near Sanaroa Island in D'Entrecasteaux group where sea fans appear to have a disease; notably a gold mine recently opened in the area. There are plenty of reefs that are as good as they were 35 years ago, some better and some worse. Chronic pollution is not a problem for most of the country. In the Bismarck Sea, corals are in excellent condition in water temperatures that hover around 30°C most of the year. Although some reefs are affected by problems, most reefs in PNG remain relatively pristine and are in good condition (from Bob Halstead, a diving industry pioneer in PNG; <http://www.halsteaddiving.com>)

**Madang:** Madang is on the north coast of PNG and the Madang Lagoon is the largest and most ecologically diverse lagoon along this coast. In 2002, 652 species of reef fishes had been recorded on the fringing reefs to about 30 m depth; representing about 61% of PNG's known fauna and 24 % of the Indo-West/Central Pacific. Madang has 4 Wildlife Management Areas (WMAs) established with local communities at Tab, Sinub, Tabad and Laugum islands. These WMAs cover 1085 ha of coral reef, mangrove, seagrass and open sea habitat (approximately 27.1% of Madang Lagoon): approximately 5.9% is protected from all extractive use; 17.8% is 'high level' managed fishery with only line fishing permitted; and 3.4% is 'low level' managed fishery with subsistence fishing allowed using non-destructive methods. The Tab Island WMA is important for dive tourism and as a year round fish spawning site. Monitoring around Madang has been conducted since the mid 1990s: by the Christensen Research Institute (CRI) until 1996 and then by Wetlands International-Oceania. Previous surveys (reported in *Status: 2004* report)

suggest that Madang Lagoon has relatively high coral cover (35–40%) but suggested declines in top predators and an increase in macro-algae. WWF are currently working in Madang. More information on LMMAs in PNG:

- [http://www.Immanetwork.org/Site\\_Page.cfm?PageID=42](http://www.Immanetwork.org/Site_Page.cfm?PageID=42)

## **FUTURE HEALTH OF THE CORAL REEFS**

The coral reefs of Australia and PNG are in relatively good condition and, combined with the remote location of many reefs and relatively small populations, the overall prognosis for these reefs is good. This is especially the case for Australian reefs such as the GBR which have comprehensive and effective management. However, many pressures remain. Climate change remains the major significant threat to coral reefs in the region, along with emerging climate related threats such as ocean acidification. The threat of climate change requires that reef resilience is maximised wherever possible. This will require effective management of fisheries and other extractive activities as well as effective, on-ground management of coastal development, water quality and pollution. Successfully managing these pressures will maintain ecosystem function and subsequently maximise resilience to the potential impacts of climate change. Effective MPA networks are seen to be a critical part of maintaining resilient reef ecosystems and well designed and managed MPAs are showing a variety of positive effects at sites across Australia and PNG.

Australia is in the enviable position of having strong community and political commitment to manage coral reefs resources and the capacity to do so. Unfortunately this capacity is weaker in PNG where marine resource management is largely reliant on NGOs working with local communities and governments at specific sites. However, there are promising signs of increasing awareness and successes in these areas which may represent a cause for cautious optimism.

Nevertheless, climate change presents a serious medium to long-term threat to coral reefs in Australia and PNG and it is certainly conceivable that some reefs may be degraded to the point where they cease to have viable coral communities while others may undergo phase shifts to persistent alternative states. Hence, efforts to maintain reef resilience should be complemented by efforts to address global climate change.

## **RECOMMENDATIONS**

- Addressing the root causes of climate change as well as taking action to maintain reef resilience is essential;
- Continue to establish and maintain effective management plans that include networks of MPAs and 'no-take' areas that provide ecologically connected refuges for coral reef species and manage the use of marine resources;
- Implement effective integrated coastal management to address pressures from declining water quality and coastal development, industrial use, land clearing, logging, agriculture and mining;
- Ensure that extractive uses such as fishing are sustainable and are adequately managed;
- Maintain capacity in research, monitoring and management in Australia and encourage major increases in capacity in WA;

- Improve coordination and management of information about coral reefs so that information is stored appropriately, traceable and retrievable; and
- Increase capacity and support for research, monitoring and management in PNG and build support for a coordinated program to implement MPAs and land and marine resource management programs with local communities, as well as programs to monitor any social and environmental changes resulting from such programs.

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### TIMOR-LESTE: THE FIRST CORAL REEF STATUS REPORTS

Timor-Leste became independent in 2002 as a country with widespread poverty and malnourishment. Coastal villages rely heavily on seafood from the nearby coral reefs; thus, there is a strong risk that reef degradation or over-harvesting could result in ecological collapse, with on-going problems for the local people. Coral reefs around Ataúro Island (30 km north of the capital Dili) and at Behau (41 km east of Dili) were assessed in 2004, 2005 and 2008. At Ataúro, there were relatively large areas of recently dead corals, probably due to destructive fishing. The larger commercial reef fish (groupers, *Serranidae*, and snappers, *Lutjanidae*; larger than 40 cm) were rarely observed, and it appeared that smaller species, such as butterflyfish (*Chaetodontidae*), were being targeted by fishers. The situation of the corals at Behau is quite different. The reef is widely used by recreational SCUBA divers and although live coral cover and total live cover were lower than at Ataúro Island, no coral bleaching or recently killed corals were recorded. Commercial fishes were also seldom observed at Behau (K41 station), although the condition was slightly better than Ataúro.

Reef degradation and over-harvesting of reef species occurs throughout the country. Probably, the first large-scale damage to the East-Timorese reefs occurred during Indonesian occupation (1975–1999), when thousands of people were forcibly displaced from the mountains to the coast in an attempt to control the independence movement. This resulted in increased fishing pressure over the reefs. Other human impacts include: blast fishing introduced by Indonesian fishermen (although this is illegal under new legislation, it occurs along the northern coast using military explosives from army/guerrilla contacts); spear fishers destroying corals in attempts to increase fish catches; damage during the construction of fish traps; mining of coral for lime for chewing betel nut (*mamamalus*) which reduces hunger pains; marine and terrestrial debris, mainly domestic, that entangles the reef framework; cyanide fishing; and fishing with *Acanthua* tree branches which contain a toxin to stun fish. The East-Timorese National Directorate of Fisheries and Aquaculture is establishing coral reef monitoring to evaluate reef areas and measure the extent of human impacts in order to improve coastal management (from Leo Dutra, Shane Penny, Narciso Carvalho, Carlos de Jesus, Constâncio S Silva, Anselmo Amaral, José Nunes, Lucas Fernandes, Celestino da Cunha, Benedito Trindade, Wayne Lovell, [leo.dutra@csiro.au](mailto:leo.dutra@csiro.au)).

## 12. STATUS OF THE CORAL REEFS IN THE SOUTH WEST PACIFIC: FIJI, NEW CALEDONIA, SAMOA, SOLOMON ISLANDS, TUVALU AND VANUATU

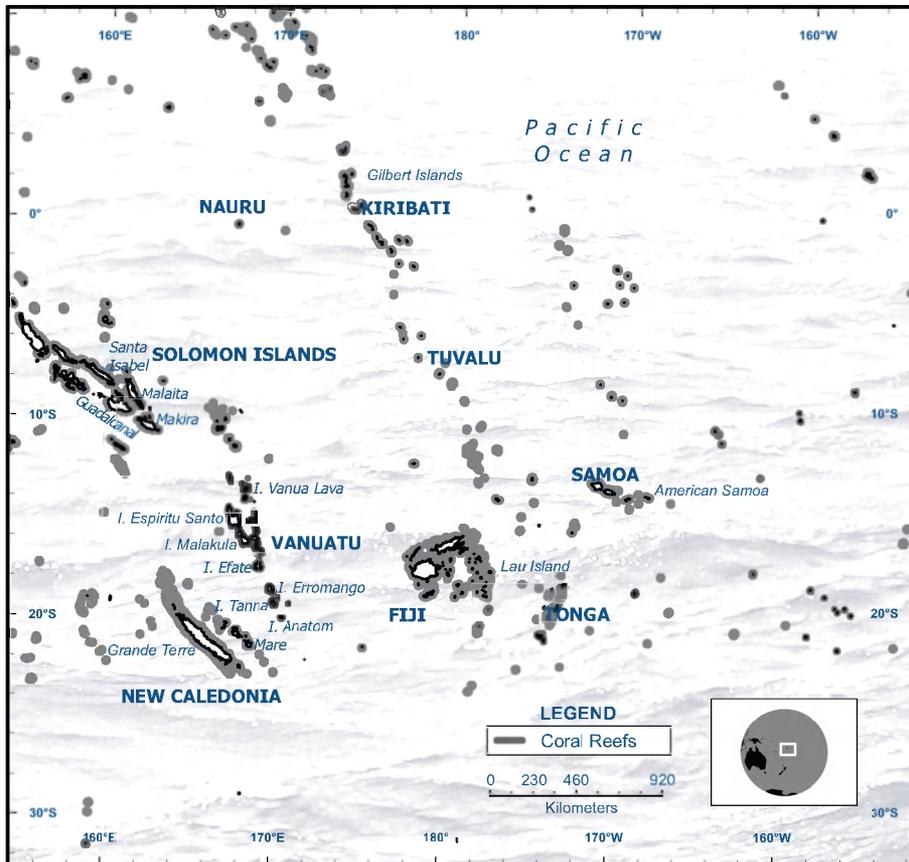
EDITORS: CHERIE MORRIS AND KENNETH MACKAY.

CONTRIBUTIONS FROM: JOYCE AH LEONG, CLAIRE GARRGUE, NELLY KERE, BRUNO MANELE, TUPULAGA POULASI, JASON RAUBANI, MARIA SAPATU, SEBASTIEN SARRAMEGNA, HELEN SYKES, CHRISTOPHER BARTLETT, SABRINA VIRLY, AND LAURENT WANTIEZ

### ABSTRACT

- Fiji, New Caledonia, Vanuatu, Solomon Islands, Samoa and Tuvalu report monitoring data for this report, with data from a broad range of observers (scientists, students, dive guides and communities); Nauru has not conducted recent monitoring;
- Coral cover has changed since the 2004 report due to effective management (positive), or local disturbances, coral predation and natural disasters (negative). Average coral cover at monitoring sites was 45% in Fiji; 27% in New Caledonia; 43% in Samoa; 30% in Solomon Islands; 65% in Tuvalu; and 26% in Vanuatu;
- Monitoring observations over 9–10 years in Fiji and New Caledonia indicate that these reefs have coped reasonably well with natural and human stressors without catastrophic changes;
- Densities of edible fish and invertebrates remained generally low (0–10/100m<sup>2</sup>) in 4 countries reflecting high subsistence and commercial fishing pressure. Butterflyfish, parrotfish, surgeonfish and damselfish were generally most dominant. High densities of parrotfish were reported from 4 countries;
- Socioeconomic monitoring is conducted in Fiji, Samoa and Solomon Islands. Greatest activity is by the Fiji Locally Marine Managed Area (FLMMA) network at 270 villages across all Fiji provinces. Most households harvest marine resources for subsistence and partially for sale, with few commercial fishers. In Samoa, more people eat canned fish than fresh fish, possibly because of decreased fish stocks in the last 10 years. In the Solomon Islands, some traditional managed systems have collapsed due to poor understanding of fisheries and resource management issues or poor national regulations. Mangrove destruction and greater fishing pressure are reducing family incomes;

- A network of temperature loggers has been established within the Node to collect long-term data on temperature relationships with coral bleaching;
- Reef related ecosystems (mangroves and seagrass) are considered important for food security, biodiversity conservation and coastal protection but less so for tourism. Seagrasses are important feeding grounds for turtles which have great traditional significance;
- There are multiple 'natural' stressors, including coral predation, temperature variation, coral bleaching, cyclones, tsunamis and earthquakes. An earthquake and tsunami in April 2007 damaged reefs and other coastal habitats in the Solomon Islands; most dramatic was uplifting of coral reef flats and exposing them to the air.
- The major human disturbances are over-fishing, pollution, sedimentation, eutrophication and coastal development;
- In response, communities, NGOs, researchers and resort owners are managing local marine areas as partnerships such that coral health and fish populations are improving;
- There is a need for long-term monitoring to understand the changes in reefs. Most monitoring is coordinated by Fisheries Departments without sufficient resources, capacity or funding. There are no recent data from Nauru as an example.



## INTRODUCTION

**General features of reefs:** Reefs throughout the South West Pacific Node are diverse and include, fringing, barrier, double barrier, submerged barrier, platform, patch, oceanic ribbon, mid ocean, atolls, oceanic atoll and near-atoll reefs; all with an estimated area of 28 364 km<sup>2</sup>. Fiji has the largest coral reef area spanning more than 10 020 km<sup>2</sup> followed by New Caledonia with 7284 km<sup>2</sup>; Solomon Islands 5750 km<sup>2</sup>; Vanuatu 4110 km<sup>2</sup>; Tuvalu 710 km<sup>2</sup>; and Samoa 490 km<sup>2</sup>. However these estimates of area vary, depending on whether just coral growth is measured, or corals plus associated lagoons.

**Importance of reefs and how they are used:** Reefs continue to play an integral part in the lives of the people of the South Pacific where coastal communities depend on them for subsistence, coastal protection and income generation. Most of the South West Pacific economies are dependant to a large extent on coral reefs, especially through the tourism sector, as detailed in the ESCAP statistical yearbook for Asia and the Pacific, 2007.

The inshore fishery is primarily carried out within coral reefs and lagoons. It is a complex, multi-species, multi-gear fishery and 70–100% of Pacific Islanders participate in reef harvesting. At least 100–400 species of fish, invertebrates and seaweeds are harvested frequently and fish consumption is high, ranging from 25–113 kg per head per year, with an average of 45 kg per head.

Men, women and children of coastal communities are involved in harvesting marine resources for food and cash income. However, commercial pressures and opportunities are overwhelming customary tenure of inshore marine resources in many areas and greater numbers of 'outsiders' (people who have no traditional connection to these resources) are increasingly harvesting coral reef resources. These include coral reef users from the tourism industry, aquarium trade and commercial fishery. This information is summarized in ReefBase Pacific ([www.reefbase.org/pacific/database.aspx](http://www.reefbase.org/pacific/database.aspx)).

Coral reef extraction activities, in addition to subsistence uses, include game fishing, decorative shell collection for ornaments/jewelry and seafood for the tourism trade; and live coral, fish, rock and invertebrates for the aquarium trade. Other extraction activities reported to impact reef status within the Node are sand and rock for construction, coral for lime (used for betel-nut chewing in the Solomon Islands) and bioactive compounds for medicine.

## STATUS OF REEFS TO 2004

There was extensive coral bleaching during 2000–2002 which affected most countries. Since then coral reefs have shown highly variable recovery with some reefs recovering fully to pre-bleaching levels of live coral cover; whereas others have shown virtually no recovery. Nauru reported coral bleaching and mass fish kills in October–December 2003, possibly due to unusually high sea surface temperatures. All countries reported that the greatest threats to coral reefs of the region continued to be human activities and cyclones, with reefs of New Caledonia, Samoa, Solomon Islands and Vanuatu having been damaged by cyclones since the 2004 status report. Cyclone Erica in 2003 destroyed 10–80% of live coral cover on New Caledonia and cyclone Heta struck Samoa in 2004 damaging 13% of the coral reefs. In mid-2004 an unprecedented number of seabirds were found dead on Nauru of unknown causes.

Momentum for the protection and conservation of coral reefs in the region has been boosted by increased participation of governments, NGOs, scientists, volunteers and local communities, especially in the implementation of resource management strategies to mitigate human pressure. Many damaging events (such as bleaching, crown-of-thorns starfish (COTS), diseases and cyclones) in the past 10 years have generated a greater awareness of the need to conserve coral reefs. Coral reef monitoring is expanding, but lacks sustainable funding and support.

**Primary threats:** These countries continue to report similar major threats in 2008 as reported in 2004. These include 'natural' disturbances such as coral predation, temperature variation, coral bleaching, cyclones; and local-scale human disturbances such as over-fishing, pollution, sedimentation, eutrophication and coastal development.

### STATUS OF CORAL REEFS: 2008

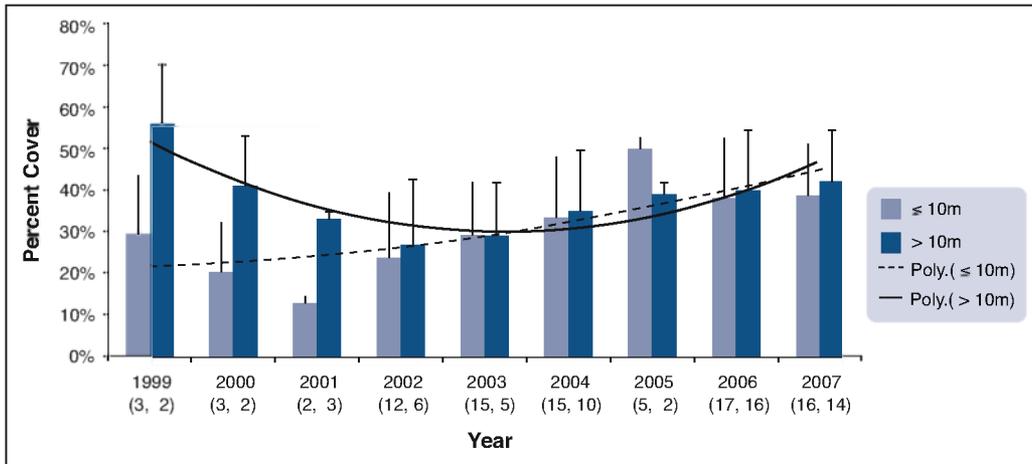
The scattered nature of islands in the South West Pacific Node provides a characteristic challenge in monitoring and conservation for the countries. Therefore, it is particularly difficult to extrapolate observations from a limited number of monitoring sites to report the status of the reefs across entire countries. For example, the reports from the Solomon Islands represent the Western Province only. Monitoring results following are grouped by region (Fiji, New Caledonia, Vanuatu and Solomon Islands); whereas Samoa and Tuvalu report status based on one monitoring location. Often the results from several monitoring teams are reported by national coordinators.

From 2003–2007 there were slight changes in substrate cover in Node countries mainly due to local impacts. For example, 2 islands with high coral cover included managed sites (North Efate in Vanuatu and Namena in Fiji). Regions with low coral cover included sites which were affected by predation of the COTS (Maitre in New Caledonia and Mamanuca in Fiji).

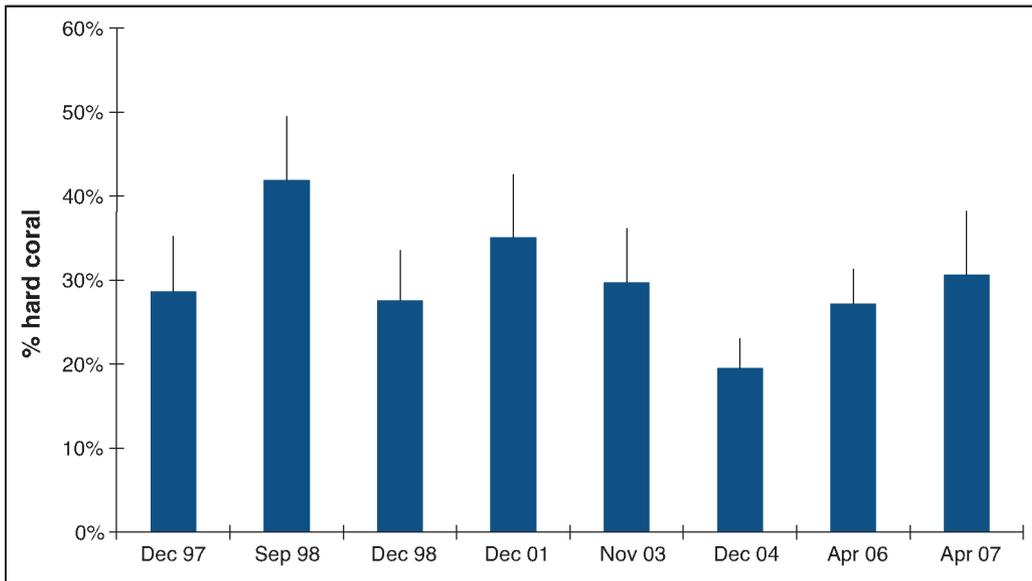
Reported coral cover in Fiji and Samoa was similar: an average of 45% across 13 sites in Fiji (range 18–62%), 8 sites in Samoa had an average of 43% (range 20–66%). Similar results were obtained from Vanuatu and New Caledonia: an average of 25% was found across 11 sites in Vanuatu (range 2–50%), and in New Caledonia the average was 27% (range 5–48%) at 10 sites. The range of coral cover in Tuvalu was similarly large with an average of 65% (range 55–98%), to that found in Fiji and Samoa, but the average was higher. Coral cover reported in the Solomon Islands (average 30%, range of 20–38%) spanned a narrower range than in Vanuatu and New Caledonia.

There were medium to high densities of parrotfish herbivores in 4 countries: 388/100m<sup>2</sup> in Samoa; 36/100m<sup>2</sup> in Tuvalu; 32/100m<sup>2</sup> in Solomon Islands; and 25/100m<sup>2</sup> in New Caledonia. Fiji and Vanuatu reported low densities of 5/100m<sup>2</sup> and 3/100 m<sup>2</sup> respectively. However, overall densities of edible fish remained generally low in all Node countries, although the most dominant indicator fish families included butterflyfish, parrotfish, surgeonfish and damselfish.

Edible invertebrates (sea cucumbers or beche-de-mer, giant clams, trochus) were also generally low across all countries reflecting the high fishing pressure for subsistence and commercial purposes. Invertebrate density was 0–1/100m<sup>2</sup> in New Caledonia and Vanuatu (with the exception of one region in Vanuatu), 0–3/100m<sup>2</sup> in Fiji and Samoa, and 1–10/100m<sup>2</sup> (with the exception of clams) in Tuvalu. No data were available from Solomon Islands.



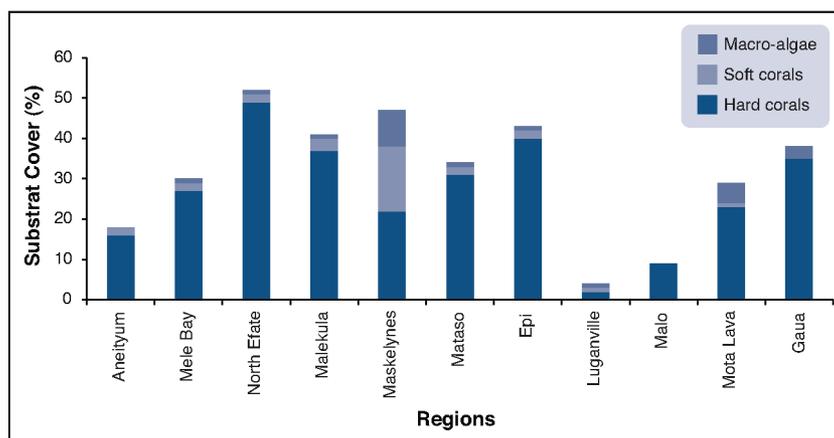
*This graph presents average coral cover from all core survey sites on reefs for 2 depth categories across Fiji. There is a clear trend of recovery following losses from bleaching and crown-of-thorns starfish, although the large standard deviations reflect the considerable variation in reef types. The lines are polynomial statistical analyses showing the trends of coral cover, and the number of sites monitored each year are presented in parentheses below the year.*



*Coral cover in New Caledonia shows considerable variation since 1997 at 6 sites around Nouméa although generally remaining healthy (at 20–40%). One site at Maitre, however, had much lower coral cover.*

Monitoring has attempted to correlate sea surface temperatures and the extent of coral bleaching events in Fiji from 1999 to 2007. The longest periods with consecutive days of temperatures over 29°C were during the years 2000, 2002 and 2005 which corresponded with the years where fully bleached and partly bleached corals were observed (2000, 2001, 2002 and 2006).

Reefs remain under human pressures (over-fishing, pollution, sedimentation, eutrophication, coastal development) as well as natural events (cyclones, tsunamis, earthquakes, coral bleaching and predation). A catastrophic event hit the Solomon Islands on 2 April 2007 when a large earthquake lifted reefs out of the water and the subsequent tsunami waves caused varying degrees of damage and disruption to coastal communities in the western Solomon Islands. The most dramatic effect was the lifting of some islands by 3 m including some major fringing reefs and also mangroves and seagrasses. These resources are no longer available to these communities which once fished and gleaned over these now dead reefs. WWF-Solomon Islands assessed the damaged sites and showed that corals were dislodged, overturned and broken in



***These data from 57 survey sites in all 11 regions of Vanuatu in 2006–2007 show that coral cover varies considerably from a low at Luganville of less than 5% to more than 50% at North Efate. The number of monitoring sites is: Aneityum (3); Mele Bay (3); North Efate (13); Malekula (7); Maskelynes (2); Mataso (2); Epi (3); Luganville (1); Malo (2); Mota Lava (3); Gaua (19).***

shallow depths, and underwater landslides cleared many steep slopes. The end result is that the affected communities have reduced shallow reef gleaning and fishing areas; although recent reports are that fish catches have not changed radically.

Recognition of degraded coral reef habitats has led to the establishment of locally managed marine areas by communities and resort owners. All countries reported an increase in the number of protected areas since 2004 and monitoring has shown that coral health and fish populations have increased in some managed areas. Vanuatu presents an interesting case study on monitoring of managed areas, which revealed that both permanent and periodic closures resulted in a higher biomass of indicator fish inside than outside the reserve. This suggests that small-scale, village-based reserves are effective resource management tools and that opening a reserve temporarily for harvest to meet occasional community needs may be compatible with conservation goals.

## SOCIOECONOMIC RESULTS

**Fiji:** The Fiji Locally Managed Marine Area (FLMMA) network consists of marine resource practitioners from government, non-governmental organizations and communities. FLMMA was established in 2001 and formally registered in 2004 and is now working in approximately 270 villages across all provinces in Fiji. Socioeconomic surveys, by the Institute of Applied Science at 29 sites, reported that the average number of houses in a village was 54, with an average household size of 5 in villages averaging 312 people. Average monthly income for all 29 villages was FJD636 (USD400), which was mainly from selling root crops (kava, yaqona, taro, etc.) and marine resources (fish, sea cucumbers), and other paid employment. Most households harvested marine resources for home consumption and some for sale, whilst a small number of people in a community are commercial fishers. The main gear used by men includes spears and nets, while women mainly used nets, fishing lines and gleaning on the reef. A major threat to fishing grounds noted in village management plans included over-fishing, as a result of the rare to non sighting of certain fish and invertebrates.

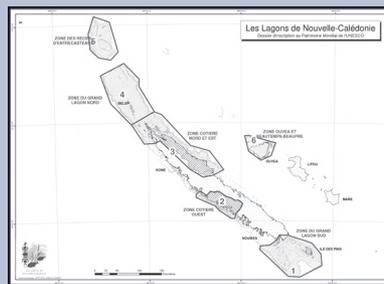
**Samoa:** A nationwide socioeconomic study by the Samoan Fisheries Division in 2006 assessed the status of rural fisheries in Samoa in 939 households in 49 villages (7778 people). People were interviewed about their household composition, income, education level, seafood purchasing and consumption habits, fishing preferences, catch, and whether they sell fish. Fishing contributed to 41% of household income and more than 20% of households were strongly dependent on fishing income to cover their expenses. Average fin fish consumption per year was 59.4 kg, (163g/day); average consumption of tinned fish was 75 kg/year (206g/day); villages closer to Apia (capital of Samoa) ate less fresh fish than those farther away; 66% of respondents felt that there were fewer fish than 10 years ago.

**Solomon Islands:** The WorldFish Center and WWF-Solomon Islands (WWF-SI) combined to assess the impacts of the April 2007 tsunami and earthquake on selected villages in the Western Province. They visited 29 locations across much of the affected area between May and June 2007, approximately two months after the event. This assessment was focused on immediate effects and needs of the coastal fisheries, including environment and infrastructure, as well as assessing on-going threats to the sustainable recovery of coastal fisheries. The assessment reported the collapse of traditional 'tambu' systems in most places; a poor understanding of fisheries/resource management issues or national regulations; a loss of community control of fisheries; relatively difficult enforcement of fisheries regulations because of extensive coastlines; marine resource management needs are more long-term in nature rather than related to immediate food security; and not all communities are equally dependent on the marine environment.

**SEM-Pasifika:** Representatives from Vanuatu, Solomon Islands, Fiji, and Tuvalu attended the SEM-Pasifika (Socioeconomic Monitoring in the Pacific Islands Initiative) training workshop held in Papua New Guinea in October–November 2007 and the SEM-Pasifika regional guidelines were published in October 2008 (available at [www.reefbase.org/socmon](http://www.reefbase.org/socmon)). Further training and assessments are expected for each country, including current assessments in Vanuatu. Results of the socioeconomic assessments will be included in future Status Reports and on [www.reefbase.org/socmon](http://www.reefbase.org/socmon).

### WORLD HERITAGE LISTING OF THE LAGOONS OF NEW CALEDONIA

In July 2008 the World Heritage Commission listed 'The lagoons of New Caledonia: reef diversity and associated ecosystems' as a serial listing of 6 marine clusters containing 15 743 km<sup>2</sup> of coral reefs, or 60% of the total reef area. The Commission acknowledged that these reefs were of global significance, noting the large numbers of species: 350 hard corals, 650 other cnidarians (jellyfish and soft corals), 1695 fishes, 841 crustaceans, 802 molluscs, 254 echinoderms (starfish, sea cucumbers, etc.), 220 ascidians (sea squirts), 203 worms, 151 sponges, 14 sea snakes, 4 turtles and 22 marine mammals. The listed area contains 9 major reef types, including fringing reefs, single barrier reefs, very rare double barrier reefs, atolls with lagoons, raised atolls and coral islets. In addition, there are extensive mangrove forests, and seagrass and algal beds, which contain 12 seagrass species, 322 recorded species of algae from 46 families; but it is estimated that another 600 to 700 species remain to be identified. New Caledonia is a territory of France with one main mountainous island, Grande Terre, the Loyalty Islands (uplifted coral platforms), the Isle of Pines and Bélep Island, 3 active volcanic islands (Walpole, Matthew and Hunter), and many atolls to the north and in the Coral Sea to the east. New Caledonia is adjacent to the Coral Triangle, the global centre of coral reef biodiversity. This, and the wide diversity of reefs and habitats in near natural state, attracted the World Heritage Commission. Whilst there was some evidence of coral bleaching and damage, probably from cyclone Erica in 2003, the corals were healthy with average live coral cover of 27.5% in 2004. Most notable are the large numbers and diversity of large fish, including top predators such as sharks, barracuda, grouper, snapper, etc. This is an important indicator of a balanced ecosystem and relatively low fishing pressure. Another important feature is the strong customary tenure and management practices of the Kanak (Melanesian) people, who were involved in developing the management framework in partnership with the French, New Caledonian and Provincial Governments. About 50% of the main island and all the offshore islands are held in customary tenure through local chiefs and villages; whereas individual land ownership is most prevalent around the capital, Nouméa, and on the west coast of Grande Terre. The World Heritage implementation is supported by specific legislation on fisheries, land and water use planning, urban development and mining. The fisheries and mining legislation are currently being revised to strengthen their environmental effectiveness (from Pierre-Yves Vion, pierre-yves.vion@dafe.nc).



**This map shows the 6 components that make up the World Heritage listing of the New Caledonian reefs, lagoons and coastal lands (copyright DTSI - New Calédonian Government)**

## **STATUS OF MANGROVES, SEAGRASSES AND FISHERIES: 2008**

Mangroves and seagrasses have been damaged during urbanization though there has been little regular monitoring. However, there is increasing awareness of the need for protection: Vanuatu and Fiji have begun to map seagrass beds in certain areas.

All countries have invested in efforts (to varying degrees) to replenish depleted marine species through aquaculture and re-stocking programs, and through protected/managed areas. Fiji, Vanuatu, Samoa and Solomon Islands have ratified the Convention on International Trade of Endangered Species (CITES), thus they have an added responsibility to control the trade of endangered species (listed in the CITES Appendix II). This is to ensure that trade is not detrimental to the survival of organisms which include scleractinian corals, live rock, giant clams and humphead wrasse (*Cheilinus undulatus*).

The most culturally important oceanic fisheries in this Node are turtles, tuna, whales and dolphins. Turtles are widely distributed throughout the region and harvesting has a long history. Turtles continue to be exploited for subsistence and traditional purposes despite harvest bans in at least 2 countries (Fiji, Vanuatu). Tuna is an important export commodity for countries and fishing licenses are issued to foreign vessels for a fee to harvest tuna in the exclusive economic zones of most countries. Both resident and migratory populations of several whale and dolphin species exist in all Node countries and are important to the tourism industry in some. However, the dolphin trade in the Solomon Islands has caused concern to all Node countries but should be regulated now that Solomon Islands have become a party to CITES.

## **FUTURE OF CORAL REEF HEALTH**

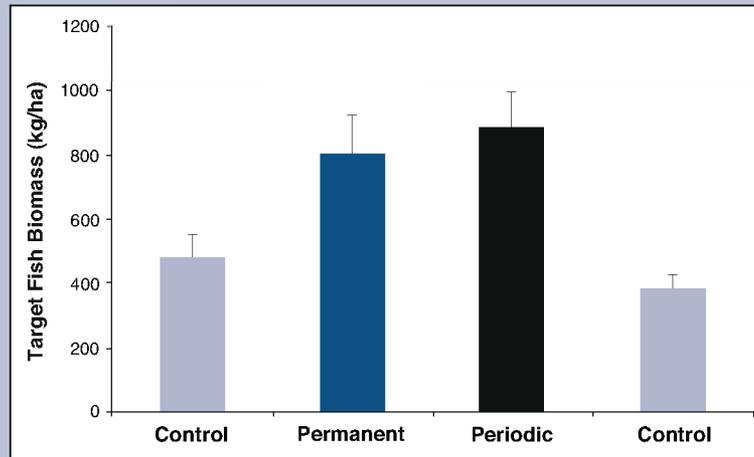
It is likely that the South West Pacific Node will experience several natural coral reef damaging events within the next 10 years. Localised coral bleaching and increasing crown-of-thorns starfish outbreaks are predicted for 2008 and/or possibly 2009/2010. If the reefs follow the patterns observed since 1999, it is predicted that poor reef health will continue across the Node in 2009–2010; to be followed by regeneration that may return coral cover to current levels by about 2014. This presumes that COTS outbreaks and La Niña conditions do not occur more frequently than current observations suggest.

Human impacts are likely to continue and become greater, particularly if political instability continues to hinder environmental management. Coastal development continues to expand and, without proper legislation and action, impacts of sedimentation, eutrophication and over-fishing are likely to degrade coral reef health along some coastlines. Uncontrolled mangrove clearing could be one of the greatest threats to reef populations in the next 10 years.

The number of locally managed marine areas are increasing (especially through FLMMA in Fiji and similar initiatives elsewhere) and this is probably the most effective measure in the region's reef 'first aid kit'. As community awareness spreads and customary owners of fishing rights become more active in conserving their own resources, more practical protection for reefs may be achieved. Networks of marine managed areas may enable conservation of reef stocks, both for biodiversity and food security purposes, despite over-fishing and development which may continue along many coastlines.

### NGUNA-PELE MPA IN VANUATU: A VALUABLE CASE STUDY

The Nguna-Pele Marine Protected Area Network is a community-managed organisation on Nguna and Pele islands in central Vanuatu, where a blend of traditional and Western management provides a valuable case study for governments, NGOs and international agencies. The primary goal of the network is the collaborative implementation of a unified area-wide strategy for the use and management of marine and terrestrial resources. Ultimately, the MPA Network seeks to improve the food and livelihood security of local residents through sharing and adaptive learning. The Network originated in 2003 when 4 area paramount chiefs decided that if they worked together they had more power to negotiate with and request assistance from national government departments and resource management NGOs. The MPA Network was modeled after previously existing island-wide networks like the Nguna-Pele council of chiefs and the Nguna-Pele Presbyterian session. Since its establishment, 16 communities have officially joined the network. Each member village has a long-term management strategy and dedicated conservation committee which sends representatives to the Network for monthly meetings. There they discuss resource management issues and area development, sharing experiences from their own village and identifying areas for collaboration. A critical role of the Nguna-Pele MPA Network is the dissemination of information; after MPA meetings each month, village representatives return to their communities with the latest and most relevant information on natural resource management. This information is both traditional and western, and is provided by local fishers, national government extension agents, local NGOs as well as obtained from overseas research and academic organizations. Most member communities of the Nguna-Pele Network have implemented marine or terrestrial closures for resource management; interchangeably called 'Tabu', 'MPA', or 'conservation area'. The motivation to establish marine closures originated from a Fisheries Department extension program conducted by trochus specialists in the 1990s. Prior to that closures were typically enacted only in preparation for, or in response to, a ceremonial or community event. Currently the Nguna-Pele area has seen a shift towards closures designed by communities for long-term resource and stock management. Many communities on Nguna and Pele have established permanent closures over parts of their tenured sea area. Some communities, however, cannot realistically close an area permanently to harvest due to high resource dependence and limited alternative livelihood options. In these cases, communities have established closures that can be periodically harvested following social and cultural requirements. Periodic harvest events are carefully controlled and monitored by communities on Nguna and Pele to ensure that long-term use goals are met. In order to understand the effectiveness of permanent versus periodically harvested reserves, the Nguna-Pele MPA Network, in collaboration with researchers from James Cook University, undertook a comparative ecological assessment. They found that periodically harvested reserves had significantly higher target fish biomass than control fished areas. These results indicate that periodic harvest in small, community-based reserves in the Pacific may be an appropriate strategy for obtaining livelihood and food security, while also meeting conservation and long-term resource management goals (from Kalpat Tarip, Manager Nguna-Pele Marine Protected Area, [marineprotectedarea@hotmail.com](mailto:marineprotectedarea@hotmail.com) and Christopher Bartlett, [CYBartlett@gmail.com](mailto:CYBartlett@gmail.com)).



***This graph clearly shows the benefits of protection with higher target fish biomass inside permanent and periodically harvested village marine reserves, compared to two comparable areas open to fishing (means + standard error).***

## CONCLUSIONS AND RECOMMENDATIONS

It is clear from these studies that a continuation and increase in monitoring activity is needed to obtain a clear understanding of changes in the composition of coral reef communities and to assist on-going reef management. Monitoring over 6–10 years has shown recovery from a bleaching event, COTS predation, cyclones and storm damage; providing evidence of considerable reef resilience in this region. However, it will probably take 20–30 years of data collection to detect if any cyclical patterns exist, such as La Niña events. The value of monitoring regular sites in the South West Pacific Node has become apparent, but cannot be continued and/or expanded unless resources are secured and committed well into the future. In addition, there needs to be consistent and continuous collaboration between all stakeholders to ensure that effective monitoring data and information are provided to coral reef resource managers in this region.

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- Other material in this chapter has been drawn from draft National chapters being written by national coordinators.

### THE VALUE OF VOLUNTEER MONITORING: REEF CHECK AND OCEANSWATCH

Probably the most extensive monitoring program in the world is on the Great Barrier Reef but only 5% of the 2900 reefs can be monitored regularly. That is where Reef Check Australia comes in. Since 2001 they have increased scientific knowledge, and especially built community support in a cost-effective manner to support reef conservation. The Reef Check GBR Project surveys >30 dive sites using local scuba divers and also out in the Coral Sea at Osprey Reef. These reefs have remained relatively stable over 8 years, except for a significant algal bloom of *Chrysozoytis fragilis* in the Cairns region in 2004 which subsequently died. COTS and *Drupella* sightings are currently low at most sites and only occasional coral bleaching and coral diseases have been seen since 2004. These data will be used to track resilience and possible climate change impacts. Reef Check Australia has developed a snorkelling program to assess grouper (coral trout) populations throughout the GBR, and the International EcoAction program has an ecotourism activity in partnership with the dive industry. Educational materials will be available online in 2009 to build stewardship for reef conservation with the younger generation. Reef Check Australia are developing an Enterprise Information System with flexible online data entry and reporting to permit sharing of raw data between scientific and management institutions.

OceansWatch harnesses the thousands of yachting and diving communities of the world to work in partnership on marine conservation and humanitarian projects in developing countries. OceansWatch has used Coral Watch and Reef Check protocols in Tonga, Vanuatu and Papua New Guinea and more projects in Asia-Pacific and Caribbean countries will be added in 2009. OceansWatch provides management and resources for projects identified by communities, scientists or other NGOs and the teams include a wide range of professional and technical skills. The Trustees organise appropriate teams and resources for projects with 2 yachts available and a fleet of purpose built catamarans being planned. Reef Check can provide training to cruising yacht crews that often travel to remote locations. Moreover they can also take scientists and volunteer divers willing to assist with in-depth surveys (from Jos Hill, Reef Check Australia, [jos@reefcheckaustralia.org](mailto:jos@reefcheckaustralia.org); Chris Bone, [chris@oceanswatch.org](mailto:chris@oceanswatch.org) or [www.oceanswatch.org](http://www.oceanswatch.org))

### 13. STATUS OF CORAL REEFS IN POLYNESIA MANA NODE COUNTRIES: COOK ISLANDS, FRENCH POLYNESIA, NIUE, KIRIBATI, TONGA, TOKELAU AND WALLIS AND FUTUNA

CAROLINE VIEUX, BERNARD SALVAT, YANNICK CHANCERELLE,  
TARATAU KIRATA, TEINA RONGO AND EWAN CAMERON

#### ABSTRACT

Status of coral reefs in the Polynesia Mana node is predominantly healthy.

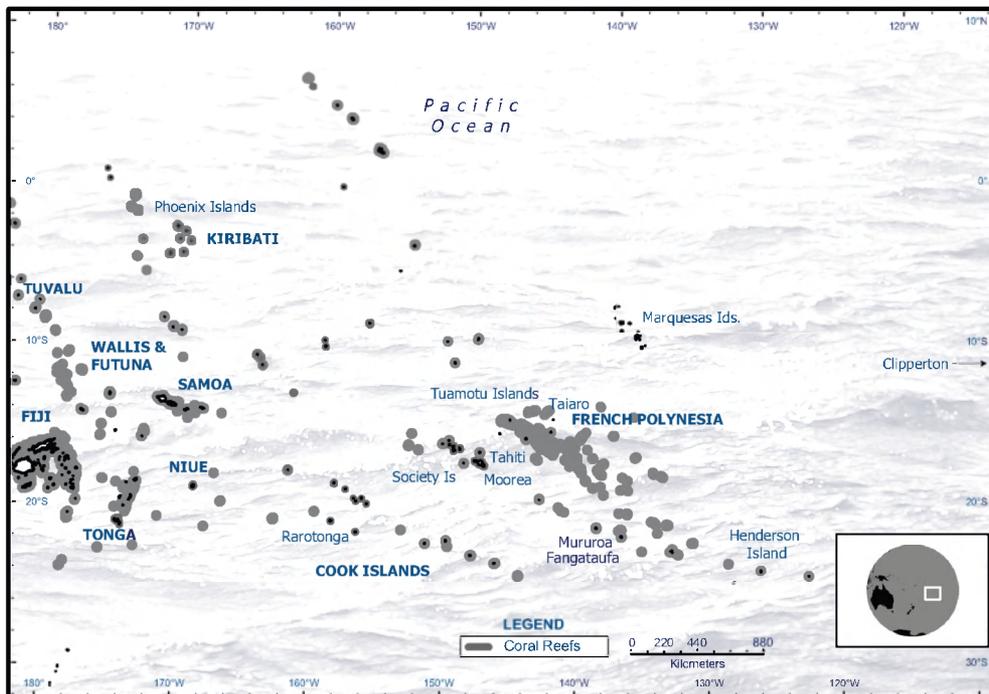
- There are 6733 km<sup>2</sup> of reefs scattered over 347 islands. Most (90%) are healthy, 5% have been destroyed or are at a critical stage and 5% are under threat;
- Reefs have been degraded around populated areas of Rarotonga (Cook Islands), Tahiti and Moorea (French Polynesia) and South Tarawa (Kiribati);
- Coral reefs support the livelihoods of Polynesian populations through subsistence fishing in all countries and through tourism and black pearl industries in French Polynesia and the Cook Islands;
- The main threats to the reefs are global warming for the remote reefs and land-based pollution for reefs near urban areas. Dynamite fishing still occurs in Wallis and Futuna;
- Reefs are mostly healthy in Wallis and Futuna, Tuamotu-Gambier and the Marquesas Archipelagos of French Polynesia;
- Reefs have largely recovered from past bleaching events in Phoenix Islands and Tarawa in Kiribati, and reefs are recovering from crown-of-thorns starfish (COTS) outbreaks in Rarotonga (Cook Islands) and from a cyclone in Niue;
- Reefs are facing a major COTS outbreak in the Society Archipelago of French Polynesia; and
- Socioeconomic assessments are now being implemented in the region, in parallel with ecological monitoring, to support coral reef management.

## INTRODUCTION

The countries of Polynesia Mana (Cook Islands, French Polynesia, Kiribati, Niue, Tokelau, Tonga, and Wallis and Futuna) have vast areas of coral reefs scattered over 12 million km<sup>2</sup> of EEZ with 347 islands representing 6000 km<sup>2</sup> of land and only half a million inhabitants. Reefs sustain tourism and black pearl industries as the main income in French Polynesia and the Cook Islands. Reef-based tourism has generated revenue of US\$130 million in 2007 and employs 60% of the population in the Cook Islands. French Polynesia produced 6.4 metric tons of black pearl in 2006, to a value of US\$100 million and employs 5000 people in more than 50 islands. Other countries have some form of tourism, usually to a lesser extent, and reefs mainly sustain livelihoods through subsistence fishing.

Until early 2004 the reefs of French Polynesia, Wallis and Futuna, Phoenix and Gilbert outer islands, and North Tarawa (Kiribati) were generally healthy. Reefs on Tokelau and Cook Islands were in a recovery stage: Tokelau after a bleaching that had probably taken place in 2002 or 2003; and the Cook Islands after a COTS outbreak that started around 1995. In the Cook Islands all sites surveyed were dominated by algae, with large populations of urchins present. Soft corals were present, indicating an early recovery stage of the reef. Another positive sign was the absence of recently dead coral, apparently stable populations of corals and no evidence of COTS, as the previous plagues have disappeared.

In Niue just as reefs were recovering from the 1990 cyclone, Ofa, Cyclone Heta hit the islands in early 2004 and had disastrous impacts on both land and reefs. About 20–90% of reefs were flattened on the west coast, where most of the economic activities occur, especially reef fisheries and tourism ventures such as diving.



In Kiribati reefs near the very populated South Tarawa atoll showed coral cover below 20% and very low diversity. This is interpreted as being due to local human damaging effects.

Global warming remains the major threat for reefs in Polynesia Mana as most reefs are located well away from major human disturbances. However, other limited disturbances are occurring in Polynesia Mana countries and water quality is generally poor around the main populated islands of the Cooks, French Polynesia, Wallis and Futuna, and Kiribati. Sand mining, dredging and ocean reclamation are also resulting in decreasing water quality. Dynamite fishing is still a threat in Wallis and Futuna; as is proximity to all major population centres such that populations of key target fish species are low as a result of over-fishing and some habitat destruction. Cyclones are a prevalent threat in the Cook Islands as they lie on a major cyclone route; in 2005, 5 cyclones hit the Cook archipelago, as well as Niue where the main damage to reefs in the past 30 years has been due to cyclones. Crown-of-thorns starfish (COTS) are also a threat for the Cooks and some islands of French Polynesia. It is worth noting the effects of volcanoes and earthquakes that regularly affect the islands of Alofi and Futuna. Although the impact on reefs of these events has not been studied, it is important to note previous experience with the last major eruption and seismic episode in 1993 which inflicted significant damage to coral populations.

### **STATUS OF CORAL REEFS IN 2008**

The following sections consider the reefs within the Polynesia Mana Node from the perspective of their status, rather than their geographic or political status.

**Healthy Reefs: Wallis and Futuna, Tuamotu-Gambier and Marquesas Archipelagos of French Polynesia.** Coral cover on the reefs in Wallis and Futuna showed a general trend of increasing cover between 2002 and 2005. Coral cover observed at the 2 permanent Wallis sites was always higher than 28%; probably due to the buffering effect provided by the large lagoon which separates the outer reefs from damaging human activities. Conversely, low coral cover values observed on the islands of Alofi and Futuna (respectively 21.4%, 7.5%, 13.3%, 15.4% on Futuna west, Futuna east, west Alofi, Alofi south-west in 2005) are very likely to be a consequence of reef proximity to the main islands.

Since 2005 concrete actions to improve environmental conditions have been undertaken or are planned (a waste treatment plant and establishment of MPAs). It is hoped that these on-going initiatives will improve the health of coral reefs over the long-term, especially in Futuna, as they are currently in an intermediate state between recovery and on-going degradation.

The vast majority of the 15 000 km<sup>2</sup> of reefs and lagoons of French Polynesia are in good health and are considered to be under low risk of degradation in the coming decades; provided that the impacts of climate change are not too strong. However, the situation of reefs and lagoons is worrying in the Society Islands.

Results of monitoring of habitats in the lagoon, and especially of key resources (fishes, molluscs and crustaceans) in the former nuclear test sites at Mururoa and Fangataufa show that short half-life elements are no longer detectable, activity of radioactive elements with an average decay period has dropped to normal background levels, and the activity of long period elements is very low and decreasing over time.

In French Polynesia there has been strong recovery of live coral cover on Moorea and Raiatea in the Society Archipelago where there had previously been serious damage from recent COTS outbreaks.

**Recovered Reefs: Kiribati.** The reefs at North Tarawa recovered quickly after the 2005 bleaching event, with the same for South Tarawa, except that there has been a decrease in coral diversity as most coral cover is now composed of *Porites rus*: few *Pocillopora* and *Acropora* species have come back. A bleaching event occurred around Tarawa at the end of 2004 and significantly damaged *Pocillopora* species, resulting in a decrease of live coral cover in North Tarawa, and a population shift from *Pocillopora* species to *Porites rus* in South Tarawa: the net effect now is that live coral cover for these sites is not significantly different. Thus in 2006 the reefs have been modified to have more of the temperature resistant *Porites* compared to more sensitive species like *Pocillopora* which both bleaches and dies in higher temperature waters. The large increase in *Porites rus* at 1 of the 2 sites in South Tarawa may be an adaptive response to human pressure: the other site shows a persistent decline in coral reef health.

Detailed surveys have been undertaken in the Phoenix Islands. Surveys at Kanton Island in 2000 and 2002 described probably the most highly developed *Acropora* species community seen anywhere in the world. In December 2004 all of this *Acropora* community was found dead. The only living coral seen was a monospecific patch of *Pavona* species. Satellite images have shown that persistent and abnormally high sea surface temperature water covered the area from August 2002 to March 2003. A survey in July 2002 reported low numbers of partially bleached colonies; thus the massive bleaching event occurred soon after that. However, surveys in 2006 have shown exceptional recovery: these results will be published shortly.

**Reefs Undergoing Recovery: Cook Islands (Rarotonga) and Niue.** A comparison of repeated surveys up to the present clearly indicate that outer reefs around Rarotonga have been degraded and a phase shift in benthic community to a more algal-dominated reef has occurred. The shift was also evident in fish community assemblages between 1999 and 2006 (no fish surveys were undertaken in the intervening years), with a general decrease in the abundance of planktivores and corallivores, an increase in herbivores, and a general increase in omnivores. While the phase shift was largely due to the recent outbreak of the crown-of-thorns starfish (COTS; lasting about 10 years), damage caused by 5 cyclones that passed in 2005 may have been minimal due to the already degraded state of the fore-reef.

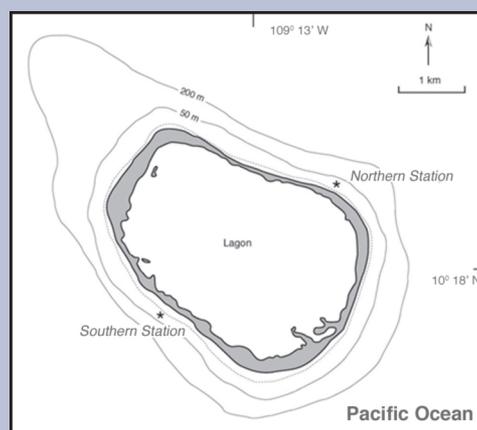
Recent coral size data indicate that 86% of colonies on the fore-reef slope were new recruits, with 82% of these being hardy to bleaching and storm resistant corals, suggesting that recovery is still in its early stages and less hardy corals are colonizing only slowly. Furthermore, the establishment of soft corals and coralline algae at leeward sites, as well as increased herbivore abundance at all sites, may be indications that conditions are well set for recovery which is now underway.

The COTS outbreak caused a massive decline in live coral cover and a proliferation of algae. A large sea urchin population developed due to proliferation of algae starting in 2003; this population is now declining in line with the decline in algal cover. An increase in soft coral cover is a sign of coral reef recovery and virtually no COTS are evident.

Bottom communities within the lagoon back-reefs of Rarotonga have high cover of turf algae, and coral colonies are larger within the lagoon than on the fore-reef, suggesting that most of the damage by COTS was on the fore-reef. Herbivores have dominated most lagoon sites with benthic invertebrate predators dominating a few sites. Macro-algae and blue-green algae were observed in all areas of the lagoon indicating that the lagoon may be experiencing elevated nutrient levels overall as a result of terrestrial runoff.

### CORAL REEF MONITORING IN THE VERY REMOTE CLIPPERTON ATOLL

During the Clipperton expedition organised by Jean-Louis Etienne in 2005, two survey stations were established between 10 and 12 m depth on the northern and southern outer slopes of the atoll. Live coral cover varied considerably with 27% average at the southern station and 63% in the north. *Pavona* and *Pocillopora* were dominant southern species (12.0% and 10.7% respectively); while *Porites* largely dominated in the north (44.3% cover). Algal cover (coralline, macroalgae and turf) was particularly high in the south (57.7%) and much lower in the north (28%). There was a high density of sea urchins in the south with 112 individuals per 100m<sup>2</sup>, mostly *Diadema mexicanum* and *Tripneustes depressus*; compared to 8–12 in the north. *Holothurian* (sea cucumber) numbers were much less (4/100 m<sup>2</sup>, south: 20/100 m<sup>2</sup>, north), predominantly *Holothuria leucospilota*. Fish abundance was similar at the two stations (208 and 284 individuals/100 m<sup>2</sup>), but species diversity (33) was richer at the south station (north, 22). These surveys showed that Clipperton Atoll has low hard coral (19), fish (37) and echinoderm (3) species diversity. Even with this low diversity, living coral cover, sea urchin abundance and fish populations are relatively high compared to other coral reefs in the central Pacific such as French Polynesia and the Great Barrier Reef. Such high coral cover and abundant, high biomass fish populations indicate that this is a healthy coral reef. Moreover, there are high proportions of large and old coral colonies with very small proportions of recently dead corals. This indicates that these reefs have not suffered major natural perturbations such as cyclones, coral bleaching or crown-of-thorns starfish plagues. There is also no evidence of direct human damage on these outer slopes of Clipperton.



Two sets of monitoring results for Niue in 2005 and 2007 show very slow recovery of the reefs. In the two sites surveyed live coral cover has not significantly increased, however, coralline algal cover has increased and turf algae decreased, showing that conditions for coral recruitment have improved.

**Degraded Reefs: Society and Austral Archipelagos (French Polynesia) and South Tarawa (Kiribati).** During the period 2003–2007 the coral reefs of French Polynesia escaped major natural disturbances, with the exception of a recent COTS outbreak. No cyclones occurred, nor have there been any major bleaching or severe algal blooms in the lagoons. Any bleaching observed was of low intensity, very localized and did not result in significant coral mortality. However, since 2006 there has been a COTS outbreak in Moorea that has already reduced coral cover on the outer slopes by 20% and COTS are also thriving in the lagoon. Thus a decrease in coral cover, as large as that seen in the early 1980s, is expected in the next few years. There are major outbreaks at several islands of the Society Archipelago (Huahine, Bora Bora, Tahaa, Raiatea, Moorea, Tahiti) and on one island of the Austral archipelago (Rurutu). No COTS outbreaks have been reported on the atolls, although several individual COTS have been seen in Fakarava.

Coral reefs near high urban concentrations of people have not undergone major human-induced degradation. However, protection of many sites has been enhanced by coral reef conservation and management measures to conserve their resources (PGEM Moorea - Biosphere Reserve and PGEM atoll of Fakarava).

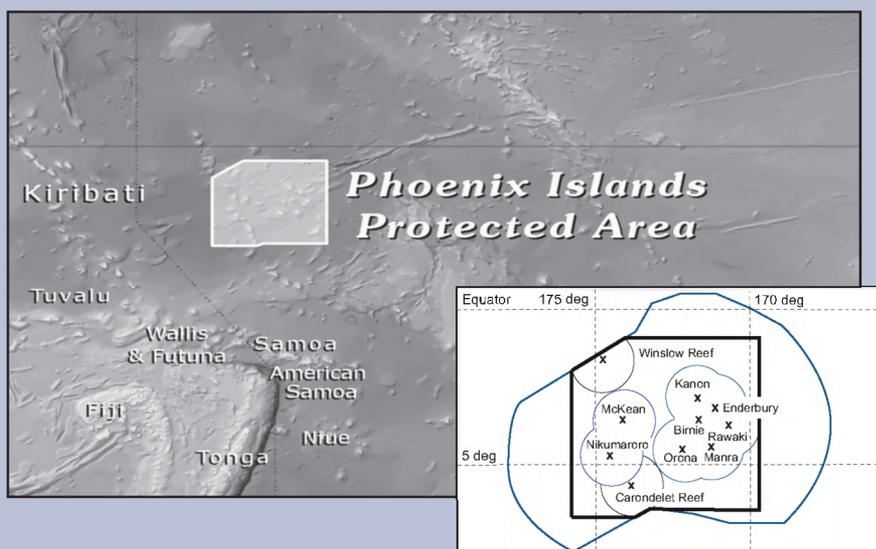
**Reefs Under Socioeconomic Assessments: Moorea, Society Archipelago, French Polynesia; and Takitumu Lagoon Conservation Area, Cook Islands.** Polynesia Mana countries have not started to integrate much socioeconomic monitoring, or even socioeconomic assessment, in parallel with ecological monitoring. The Pacific region launched the GCRMN socioeconomic monitoring guidelines (SEM Pasifika) in 2008 and, along with some funding, it is expected that the next status reports will contain a much larger socioeconomic component.

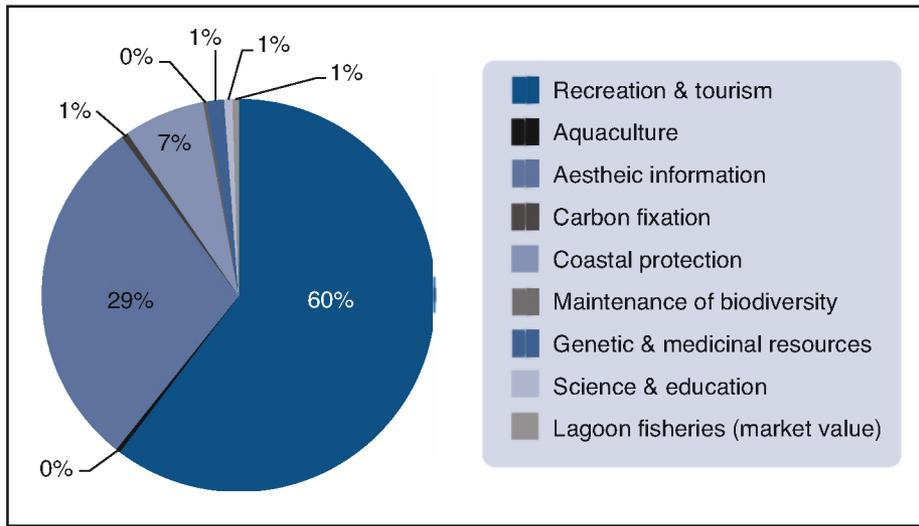
Moorea in French Polynesia is a high volcanic island of 150 km<sup>2</sup> surrounded by a coral reef and lagoon ecosystem of about 50 km<sup>2</sup> that has recently been assessed to evaluate the goods and services reefs provide: recreation and tourism (58%); aesthetic values (housing, 28%); coastal protection (7%); maintenance of biodiversity (5%); and just 2% in providing food from fisheries. Moorea is a relatively densely populated island with 15 000 people and is the sister island of Tahiti, such that it now functions as a suburb of Tahiti Papeete, the major urban centre of commerce and government activities. A management plan of the lagoons and reefs (PGEM) was launched in order to solve conflicts of interest among all stakeholders.

Socioeconomic data on the economic exploitation of coral habitats and resources are available in French Polynesia. Reef fisheries catches are about 3400 metric tons per year, with take decreases in crustaceans and increases in giant clam (*Tridacna maxima*); 125 tons of *Trochus niloticus* (for buttons and paint) was exported in 2006; and black pearl production, which was 11 tons in 2000, had fallen to 6.4 tons in 2006.

### PHOENIX ISLAND PROTECTED AREA: THE WORLD'S LARGEST MPA

The small Pacific island nation of Kiribati has become a global conservation leader by establishing the world's largest MPA (410 500 km<sup>2</sup>). The Phoenix Islands Protected Area (PIPA) conserves one of the world's last intact oceanic coral archipelago ecosystems, consisting of 8 coral atolls and 2 submerged reef systems in a nearly uninhabited region, with abundant marine and bird life. PIPA also includes underwater seamounts and other deep-sea habitats. The New England Aquarium has led 3 research expeditions since 2000 and found high marine biodiversity, including more than 120 coral species, 520 fish species; including some undescribed species. PIPA contains some of the most important seabird nesting populations in the Pacific, as well as healthy fish populations, including large numbers of top predators, along with healthy sea turtle populations. This biodiversity illustrates the pristine nature of the area and its importance as a reservoir and migration route. Protecting the Phoenix Islands means restricting commercial fishing, resulting in a loss of revenue for the Kiribati government that would have come from issuing commercial fishing licenses. The New England Aquarium and Conservation International (CI) are helping Kiribati design an endowment system to cover the core recurrent management costs of PIPA and compensate the government for the foregone fishing revenues. The management plan permits subsistence fishing by resident communities and other sustainable economic development in designated zones. Kiribati first declared their intention at the 2006 Conference of the Parties to the Convention on Biological Diversity in Brazil. On 30 January 2008, the Government of Kiribati adopted formal regulations for PIPA to double the original size and make it the largest MPA in the world. The development of PIPA was a partnership between Kiribati and the New England Aquarium including joint scientific research, with funding and technical assistance from the CI Global Conservation Fund and Pacific Islands Program, which is part of the Coral Reef InitiativeS in the Pacific (CRISP) program.





*This pie chart (or ‘camembert’ in French) presents the economic goods and services (in US\$) provided by the coral reefs and lagoons of Moorea, French Polynesia. An assessment was made of the possible economic contributions, but these 9 (of the total 20) represent most of the value. Of particular note are the non-extractive value of tourism and aesthetics which reinforce the need for effective management of damaging impacts (pollution, over-fishing, and possibly control of COTS plagues) to sustain these values (from Charles, M. 2005, Masters Thesis).*

In the Cook Islands, the Takitumu Lagoon Pilot Program is a component within the Cook Islands Marine Resources Institutional Strengthening (CIMRIS) project. This aims to enhance the management of sustainable marine resources for Cook Islanders. The Takitumu Vaka Council (TVC) provides supervision over the Takitumu Lagoon Management Plan and conducted a series of surveys focusing upon households, tourism accommodation owners and managers, to identify and channel local support to help management of their lagoon. Some of the results were as follows:

- Overall, 61% of households ticked the ‘very strongly’ box when asked if they support the TVC to lead the Lagoon Management Plan;
- The health of the Lagoon was perceived to have deteriorated over the past 10 years in the 3 villages, falling from average scores of 3.77–4.09 down to 1.59 – 2.33 (1=much polluted, 5=very healthy);
- Important uses of the lagoon for households were recreation, a source of food, ‘identity’ and pride, health, tourism and livelihoods. The tourism operators response was 99% in terms of importance for guests and business;
- When asked about work needed to be done for the lagoon project, overall 6% of the household participants considered enough was done, 99% of tourism operators felt insufficient resources had been committed to the project; and
- Pig effluent was perceived to be the major cause of deteriorating lagoon health by 3 villages, followed by septic tanks and sediment runoff. Climate change threats rated the lowest in all villages.

## CONCLUSIONS

The 6733 km<sup>2</sup> of coral reefs in Polynesia Mana are mostly healthy and under low threat levels (3% regarded as destroyed, 2% at critically threatened stage, 5% moderately threatened, and 90% at low or no threat level), unless global warming threats become more severe in the next few years. The main reasons for this healthy status is the low human populations living in the area, thereby resulting in very low pressures on most coral reefs and associated fisheries, as well as the isolation of these archipelagos in the Central and East Pacific far removed from continental influences.

Despite this general healthy status, reefs have been destroyed or degraded during the last 4 years through natural events such as cyclones in Niue and the Cook Islands, COTS outbreaks in French Polynesia and bleaching in Kiribati. Human activities are putting an ever increasing pressure on reefs around populated islands, such as Rarotonga, the Society Archipelago (Tahiti and Moorea) of French Polynesia or Tarawa, Kiribati. These reefs are clearly being degraded with evidence of reduced coral cover and water quality, overgrowth by algae, reduced and changed fish populations and the presence of solid wastes, especially plastics. On most reefs the poor water quality due to unsustainable land management and sanitation are the main threats. Over-fishing is a localised threat around these populated areas but many no-take zones and other fishing regulations, such as PGEM in Moorea, have been implemented to mitigate it; success of these measures has been demonstrated at many sites. The high prevalence of ciguatera fish poisoning in populated area such as Rarotonga acts as a great mitigation measure in reducing the catch of large, potentially toxic fish species.

One positive example is the Taiaro Biosphère Reserve in the Tumaotu Archipelago, which was established in 1977 by the Man and Biosphere Programme. A small uninhabited atoll was created as a strict nature reserve and was extended in 2007 to include neighbouring atolls, such that the new Biosphere Reserve now includes 7 atolls (Aratika, Fakarava, Kauehi, Niau, Raraka, Taiaro and Toau).

## RECOMMENDATIONS

- There is a need to better integrate watersheds in the coastal management of populated islands because the main sources of coral reef degradation come from the land as increased sediments, nutrients and solid wastes;
- Coral reef monitoring needs to include both ecological and socioeconomic aspects and should be included in government service program activities in order to be sustainable and not project based;
- Coral reef monitoring should be closely associated with management plans, for example in the designation of protected areas, to assess the effectiveness of management activities, and to demonstrate the direct benefits of effective management to stakeholders and adjacent islands and countries; and
- Parallel ecological and socioeconomic monitoring should be implemented in all countries to assist resource management agencies make balanced decisions on conservation and sustainable exploitation.

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## 14. STATUS OF CORAL REEF RESOURCES IN MICRONESIA AND AMERICAN SAMOA: 2008

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### ABSTRACT

- Coral reefs in Micronesia and American Samoa appear to be amongst the most resilient in the world, despite numerous on-going threats;
- There has been considerable recovery of reefs in western Micronesia (especially Palau) that were devastated during the massive coral bleaching in 1998;
- The more remote islands support thriving communities of large reef fishes due to limited fishing pressures and habitat degradation;
- Fish populations around major population centres show clear signs of over-fishing with few large fish observed because of fishing pressure, particularly spear-fishers using scuba;
- Management and monitoring efforts are on-going throughout the region and numerous effective initiatives are promoting recovery of damaged coral reefs as well as the conservation of healthy ones;
- Lack of enforcement continues to be one of the major hindrances to effective resource management outcomes and more support is necessary.

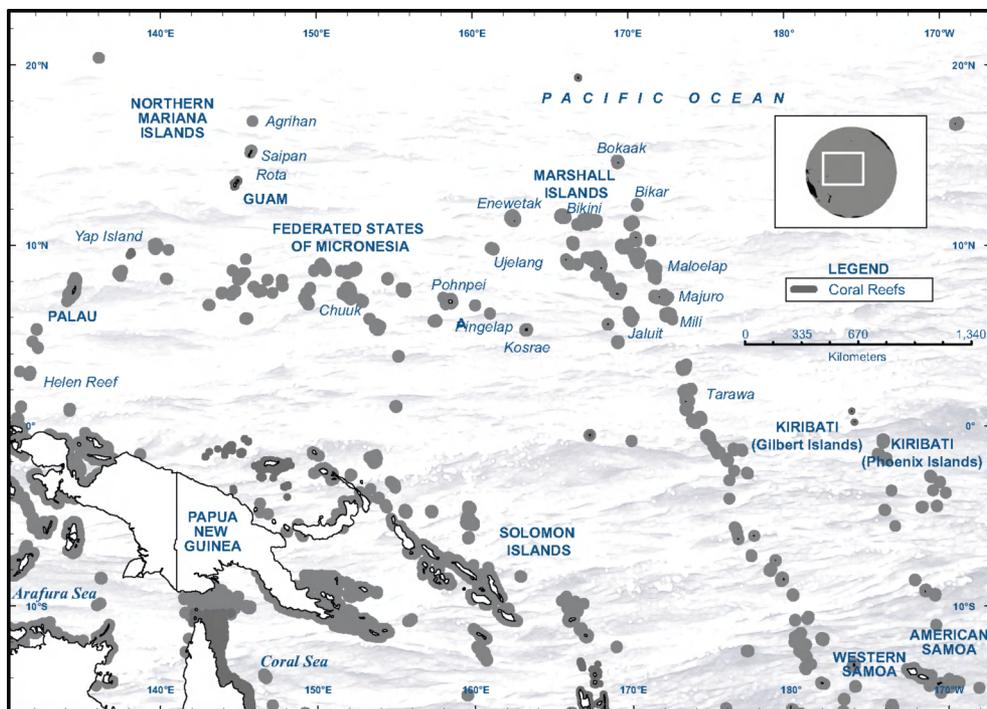
## INTRODUCTION

This chapter has been assembled by coral reef experts across Micronesia and in American Samoa and essentially summarizes more detailed information contained in: *The State of Coral Reef Ecosystems of the United States and Pacific Freely Associated States: 2008*; the full text is available at: <http://ccma.nos.noaa.gov/stateofthereefs>.

**American Samoa:** The Territory of American Samoa consists of 5 volcanic islands and 2 atolls in the central South Pacific Ocean. The islands are small, ranging in size from the heavily populated main island of Tutuila (142 km<sup>2</sup>) to the uninhabited and remote Rose Atoll (less than 1 km<sup>2</sup> of land). The volcanic islands are surrounded by fringing reefs, while the atolls have steeply sloping sides, and Rose Atoll has a lagoon. More than 2,700 species of corals, fish, invertebrates, marine plants, turtles and marine mammals are known.

**Commonwealth of the Northern Mariana Islands:** The 14 islands that make up CNMI lie on a north-south axis in the western Pacific basin and stretch approximately 600 km with the Pacific Ocean to the east and the Philippine Sea to the west. The southern islands of the archipelago are uplifted limestone, whereas the northern islands are volcanic.

**Federated States of Micronesia:** The Federated States of Micronesia (FSM) is comprised of 607 islands found within the states of Chuuk, Kosrae, Pohnpei and Yap, covering 1.6 million km<sup>2</sup> of ocean. FSM has a total landmass of 702 km<sup>2</sup> comprised of high volcanic islands, low reef islands and atolls. Each island or group has its own language, customs, local government, and traditional system for managing marine resources. Islanders have a strong cultural and economic dependence on coral reefs resources.



**Guam:** This U.S. territory is the most southern, largest and most populated island in the Mariana Archipelago and in all of Micronesia with 173,500 people living on 560 km<sup>2</sup>. Guam has more than 5,100 marine species, including 1,000 nearshore fish species and 300 species of hard coral. The primary threats to Guam's coral reefs include runoff from land, storm activity and over-fishing, as well as other threats including crown-of-thorns starfish (COTS) outbreaks, coral diseases, dredging, boat groundings, marine debris, coral bleaching, and recreational misuse and overuse. The plans to expand the military presence on Guam pose significant threats to coral reef resources due to a projected population increase of up to 60,000 people and numerous associated construction projects.

**Palau:** Palau is the most western archipelago in Oceania, has the most diverse coral reef fauna of Micronesia and is home to the highest density of tropical marine biota of any comparable geographic area in the world. An estimated 425 coral species and 1,700 fish species are found in Palau and the culture and economy have historically gained sustainable food supplies from the reefs. Dynamic multi-species fisheries involve individual fishers feeding their families, providing food for traditional customs and selling to commercial markets, restaurants and to selective buyers for export. Tourism has been the major component of economic growth in Palau and visitor numbers are increasing annually; the majority of which are sport divers.

**Republic of the Marshall Islands:** The Marshall Islands are comprised of 29 atolls and 5 low reef islands grouped into two north-south oriented chains. There are nearly 300 coral and more than 800 fish species, and most reefs are virtually pristine with very high coral cover (50-90%) and relatively high algal cover. The country has been relatively unaffected by over-fishing, destructive fishing, coral bleaching, sedimentation, coral disease, and COTS outbreaks, although remote atolls are targeted for shark finning. The highly populated atoll of Majuro has suffered rapid, profound degradation and high fishing pressure leading to reductions in fish communities and declines in coral diversity. The RMI has one of the few remaining healthy populations of humphead wrasse (p. 52) and predominantly healthy shark populations. Some outer atolls are considered very healthy and pristine with abundant megafauna despite no take zones being only recently initiated. Ailinginae Atoll and Bikini Atoll will be nominated for World Heritage status in early 2009.

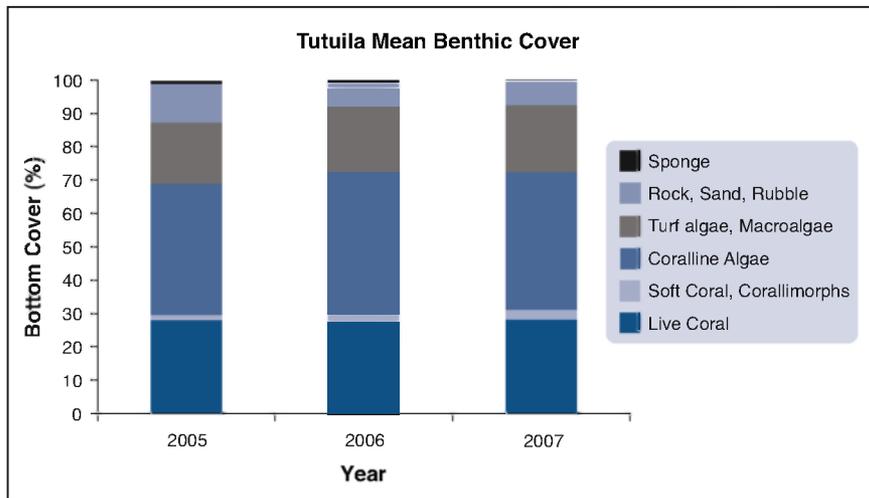
### **STATUS OF CORAL REEF BENTHOS: 2008**

**American Samoa:** Coral communities in American Samoa have been exposed to an extensive series of major disturbances including: a COTS outbreak in 1978 which killed many corals except on the reef crest; major hurricanes in 1987, 1990, 1991, 2004 and 2005; mass coral bleaching events in 1994, 2002 and 2003; and extreme low tides in 1998, 2005 and 2006. Before the 1978 COTS event, reefs were dominated by table and branching *Acropora*, and coral cover at selected sites was estimated at 63%. Subsequently, reefs have been dominated by coralline algae and encrusting corals, although some areas are now dominated by *Acropora* and thus appear to have recovered. The reefs in American Samoa appear to be in good condition and are resilient to repeated disturbances.

There are at least 5 different monitoring programs, and all report about 28% coral cover around Tutuila, high coralline algae cover on the south side of Tutuila and more turf algae on the north side. The Territorial Monitoring Program has found no significant changes in bottom cover since 2005. There are very few dead corals on reef slopes (less than 5% of all coral) and

virtually none have been recently killed. Outer reef flats currently have about 21% coral cover and inner flats have 10%.

In 2007 the U.S. Fish and Wildlife Service successfully removed all debris from a Taiwanese long-liner that ran aground on Rose Atoll National Wildlife Refuge in 1993. The cleanup removed more than 200 tons of debris and corals are now showing recovery from the 1993 shipwreck, 1994 bleaching event and 2005 hurricane. However, giant clam populations and reef fish populations have declined during recent years; unauthorized fishing is the likely reason.



***Coral communities around American Samoa have been relatively consistent in benthic composition since 2005, with total hard and soft coral cover at monitoring sites around 30%.***

The NOAA Pacific Island Fisheries Science Center, Coral Reef Ecosystem Division (PIFSC-CRED) research cruise found coral cover to be similar at Ofu-Olosega and Tutuila, but higher at Swains and lower on Rose Atoll. A very large bloom of the encrusting colonial ascidian, *Diplosoma simile*, is overgrowing corals at Swains Island and patches of a corallimorph, *Rhodactis howesii*, are expanding to cover significant areas around Tutuila. Coral and coralline algal diseases are present, yet are generally uncommon. Sediment runoff is significant during heavy rain events and has damaged several local reefs. Nutrient runoff from piggery wastes, high phosphate detergents, septic systems, and non-point sources are also a problem on nearby reefs.

Coral reefs in Pago Pago harbor were severely damaged by massive human impacts from the 1950s to 1990s including dredging, infilling, sediment runoff, and the discharge of tuna cannery wastes. A transect started in 1917 on the reef flat at Aua is one of the oldest coral reef monitoring projects in the Pacific and showed steady declines in coral cover and predominant cover of dead rubble. Small areas of reef flat communities near the mouth of the harbor have high cover of healthy corals along the reef crest. Introduced species, ship groundings, tourism, marine debris, and collection for trade are all minor threats. All future human threats will be exacerbated by rapid and unsustainable population growth, which has grown from fewer than

10,000 residents in 1910 to an estimated present population of 69,000; projections are that this population will double within 40 years. As the entire territory is a coastal zone with limited habitable space, these population pressures will undoubtedly increase in the years ahead and are currently being addressed by a multi-agency local action strategy.

**Commonwealth of the Northern Mariana Islands:** Coral diversity and colony surface area are significantly lower on the northern islands than the southern (62 species per site and 206 cm<sup>2</sup> versus 82 species and 312 cm<sup>2</sup>). NOAA's Marianas Research and Monitoring Program (MARAMP) surveys revealed highly variable levels of coral and algal cover between islands: the highest overall coral cover was found at Pathfinder (25%) and Maug (22%). A standardized method for naming coral diseases has recently become available, but it is difficult to compare coral diseases on Saipan to elsewhere in the Pacific. Non-point source pollution remains one of the primary localized threats to coral reefs as decreases in species richness and recruit abundance, coupled with an increased dominance by a few coral species, is becoming apparent at sites influenced by watershed pollution; no such trend exists at other sites.

**Federated States of Micronesia:** The coral reefs of the FSM are in good health; coral bleaching and disease are rare and impacts from tourism, cyanide fishing, live coral/fish trade and storms are minimal. People in the FSM depend heavily on coral reefs for food and revenue from fish sales and tourism. Over-fishing, impacts from land-based activities, climate change, and an erosion of traditional management systems have led to a general decline in coral reef resources, especially near population centers. Recent coastal infrastructure development has led to increased sedimentation and the degradation of near-shore coral reefs. Residential and business developments on the coast also contribute significant sediment loads and inadequate waste management results in solid waste accumulation along the shore.

Each state has two government agencies which manage coral reefs (Marine Resources Departments/Divisions and Environmental Protection Agencies) with the support of local and regional organizations such as the Yap Community Action Program (Yap CAP), Chuuk Conservation Society, Conservation Society of Pohnpei, Kosrae Conservation and Safety Organization, the Secretariat of the Pacific Region Environmental Programme (SPREP), and the Nature Conservancy. Monitoring has been on-going in each state since 1994. On-going coordination efforts between the Palau International Coral Reef Center and NOAA will continue to support the first regionally-coordinated monitoring program within Micronesia.

Chuuk State has identified 30 Areas of Biodiversity Significance covering 97,773 ha as the basis for establishing a long-term monitoring program. A rapid ecological assessment was recently completed and a biodiversity gap assessment is planned for late 2008. Kosrae coral reefs are in good to excellent condition with hard coral cover ranging from 40% to 60%; however more effort is needed to reduce the impacts of coastal development, soil erosion and sediment flows. Pohnpei's reefs contain nearly 350 coral species but they have been damaged by sediment runoff, dredging and COTS which have reduced species composition and the structure of the coral communities while hindering recovery. There is little to no evidence of destructive fishing, impacts from boat anchors or sport diver damage. The existing coral monitoring programs were refined in 2004 to support decision making to improve the health of Pohnpei's coral reefs. Coral reefs on Yap are in relatively good condition and have the highest diversity in the FSM with 215 coral species. These reefs have historically thrived under traditional management practices yet recent larger scale resource uses and other uncontrollable factors, such as coral bleaching,

COTS, destructive fishing, coastal development and ship groundings, are undermining these practices. Marine ecosystem degradation occurs around development areas and coral reefs are becoming sources of major economic benefit but via contrasting roles in construction, export, and tourism. Yap CAP, in collaboration with the Yap State Environmental Protection Agency and Marine Resources Management Division, started annual monitoring at 6 sites in 2006.

**Guam:** Coral reefs in the north and south at sufficient distances from rivers are relatively healthy, while large areas of reef in the south, particularly near river mouths, are in fair to poor condition. Chronic COTS outbreaks have stripped many reefs around the island, including some reefs with previously high coral cover and diversity. Average coral cover on the fore reef slopes was 50% in the 1960s but by the 1990s it had dwindled to less than 25% with only a few sites having more than 50% cover. Degradation of water quality, chronic COTS outbreaks, low abundance of major herbivore fish species and other persistent stressors are lowering reef resilience and recovery potential. A particularly distressing indicator is the marked decrease in coral recruitment rates during the last few decades.

A comprehensive coral reef monitoring program was recently initiated, although island-wide rapid assessments conducted by NOAA in 2003, 2005, and 2007 contribute substantially to the understanding of coral reef status and trends. Coral cover in 2005 ranged from 11.8% on the southwest coast to 38.2% on the west side of the island, with an average cover of 26%. Coral cover is similar in the west/northwest, east/northeast, and east/southeast regions of the island (25%, 26%, and 26%, respectively), while coral cover was lowest in the west/southwest region (12%).

Coral disease prevalence is high and potentially problematic as determined by University of Guam Marine Lab (UOGML) at 10 sites in 2006. Coral cover ranged from less than 10% at Pago Bay site to greater than 80% at one site in Apra Harbor. Extremely high sedimentation rates continue to devastate reefs near river mouths: a 2005 National Park Service study found that sedimentation rates in Asan Bay were among the highest in the literature, ranging from 0.045 to over 2.0 g/cm<sup>2</sup>/day. The extremely elevated rate of sedimentation and drastically reduced rates of coral recruitment raises serious concerns about the long term health and survival of Guam's coral reefs. A 2004 UOGML study in Fouha Bay, in southwestern Guam, showed that sediment from runoff during heavy rain damaged corals and resulted in a steep decline in coral species richness over a 25-yr period; more than 100 species were reported in 1978, fewer than 50 in 2003. Macro-invertebrate surveys indicate relatively low abundance of the more conspicuous invertebrates, except for high urchin and COTS densities at some sites.

**Palau:** Palau has the highest coral species diversity in Micronesia, yet human and natural threats to coral reef health such as over-fishing, sewage outflow, sedimentation, and a rapidly growing tourism industry are increasing.

Although coral mortality was as high as 90% in some areas after the 1998 bleaching event, recovery has been tremendous. The Palau International Coral Reef Center has monitored 22 sites since 2001 and found that coral cover has increased at an annual rate of 2.9% from 2001 to 2004. The average coral cover across all monitoring sites in 2004 was 31%. Surveys from 2006-2007 show continuing recovery and increased coral cover at all sites. In addition to the Protected Areas Network Act of 2003, which supports local communities in setting up MPAs, the *Micronesia Challenge* is a specific initiative originally proposed by the President of the Republic of Palau that has attracted wide support (p. 48).

**Republic of the Marshall Islands:** Coral reefs on outer islands and atolls with relatively small populations have not changed significantly since 2004 and no major mortality or degradation has been reported. RMI has suffered little coral mortality from bleaching, although Majuro typically experiences inter-tidal, annual reef flat bleaching. Majuro's reefs have experienced significant changes since 2004 due to major increases in coral diseases, such as white syndrome and CLOD, as well as COTS outbreaks. Less than 1% of Majuro reefs have been lost to dredging yet 30-50% of corals in the lagoon have recently been devastated by a COTS outbreak, with at least 20% having a persistent algae-dominated condition as a result. Further, 30% of Majuro oceanic reefs have suffered high disease mortality of table corals. The Micronesia Challenge, with its pledge to effectively conserve 30% of marine resources, signed in 2007 by former President Note, has increased both local and international efforts to protect reef ecosystems.

### STATUS OF MANGROVES AND SEAGRASSES: 2008

**American Samoa:** American Samoa lies towards the eastern periphery of mangrove distribution so their presence within the territory is limited. The major mangrove stands in Pala Lagoon on the south coast of Tutuila continue to dwindle due to coastal development and land based sources of pollution. Little is known of the status of the remaining small mangrove stands in the Territory although the majority is found on Tutuila, Aunu'u and Ta'u. The only seagrass bed present is very small and incapable of serving as fish habitat.

**Guam:** Mangrove growth on Guam is limited to 70 ha on the eastern shore. Mangroves are protected against un-licensed removal and reclamation; however this protection is inadequate to address multiple other threats such as filling, road construction and oil spills which have caused mangrove declines. Some mangroves in Apra Harbor will probably be affected during the upcoming military expansion. No recent studies have been conducted on Guam's mangroves since the island-wide inventory in the mid 1970s. Island-wide benthic habitat mapping by the UOGML showed seagrass beds occupied 3.1 km<sup>2</sup>, or approximately 2.8% of Guam's nearshore waters (< 40 m water depth).

**Palau:** Palau has about 45 km<sup>2</sup> of mangrove and swamp forest area around the east and west coast, including the remote islands of Meriil and Pulo Anna. A mangrove survey in 2006-2007 added two new mangrove species records to the Palau Mangrove Management Plan, *Xylocarpus moluccensis* and *Sonneratia caseolaris*. Seagrass areas have always been an important subsistence fishing habitat for local communities in Palau. Prior to Palau becoming a member of the Global Seagrass Monitoring Network in 2001, few seagrass studies were done in Palau, e.g. a 1980 study identified 10 seagrass species in Palau.

**Republic of the Marshall Islands:** Mangroves are limited in the atolls of the Marshall Islands and are mostly confined to the southern, wettest atolls. The depressed centres of some of the larger atoll islands support stands of mangroves, and a few stands of red mangroves *Rhizophora* were noted in the lagoon of Arno Atoll during 1988 coral reef surveys. Undoubtedly, additional mangroves will be reported once a country-wide inventory is accomplished.

### STATUS OF CORAL REEF FISHERIES

**American Samoa:** Coral reef fish assemblages around Tutuila are dominated by herbivores and detritivores such as surgeonfish, small parrotfish, and damselfish. Reef fish populations of small

to medium size fish are relatively good, but all of the larger reef fish species are uncommon to rare. The standing stock and size structure of fishes is lower on Tutuila compared with the Manu'a Islands, Rose Atoll and Swains Island, where human habitation and visitation are low. Overall biomass levels of reef fish are similar to literature values for other fished reefs in the mid-Pacific region, but remain one third the biomass values found at unfished reefs. Large fishes such as sharks, snappers, jacks, and groupers are rare, especially around Tutuila. Reef fish catches and effort have declined over the last 50 years as the population shifted from subsistence food sources to a cash-based economy. Generally, active-selective gear like spearfishing and gleaning resulted in a decrease in CPUE, while passive-non-selective gear like throw nets and hook and line remained constant or had increasing CPUE.

**Commonwealth of the Northern Mariana Islands:** PIFSC-CRED found that fish assemblages have remained relatively consistent during the past 3 years. There is a greater biomass of larger fish in the northernmost islands (0.25 ton per ha) compared to the middle section of the island chain (0.13 ton per ha) and the heavily populated southern islands (0.05 ton per ha). Sharks are scarce throughout the archipelago and the ban on the use of scuba spearfishing on Saipan has improved the abundance of food fish groups. Monthly catch data is sent to PIFSC's WPacFin program which maintains fisheries data across the Pacific at: <http://www.pifsc.noaa.gov/wpacfin/cnmi/Pages/>.

**Federated States of Micronesia:** Over-fishing is the most urgent and critical threat to marine resources in the FSM and the breakdown of traditional management systems has contributed to this problem. In Chuuk, over-harvesting and dynamite fishing are the greatest concerns for coral reef ecosystem health, especially near population centers. Approximately 610 species of reef fish have been recorded, although approximately 750 species are predicted to exist.

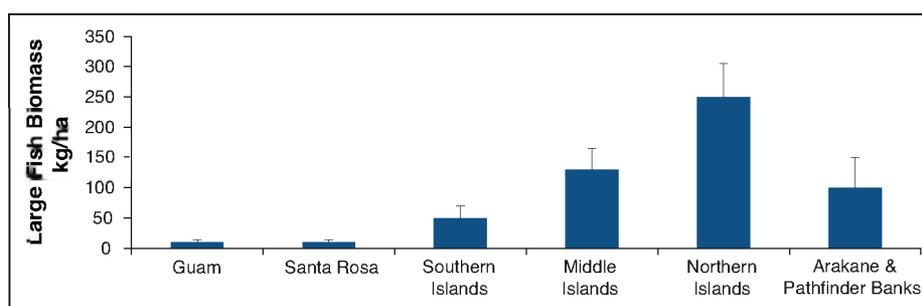
In Kosrae, destructive fishing methods are commonly used by fishers and certainly damage fish populations. Some fish genera were missing during 2006 rapid ecological assessment in Kosrae compared to a 1986 survey. A few humphead wrasse (*Cheilinus undulatus*) were recorded but no bumphead parrotfish (*Bolbometopon muricatum*) were seen, most likely due to over-fishing. About 200 species are considered as common food fish and Kosrae has recently limited the export of reef organisms except for personal and family use (p. 52).

Local fisheries in Pohnpei are being unsustainably over-fished and 70% of fish sold at markets are immature or found with eggs. Night-time spearfishing is the most popular type of fishing and this overly efficient method is contributing to the overall decline in reef fisheries. Without an overarching policy that combines habitat protection and fishery management, Pohnpei's marine environment will continue to decline dramatically. Over 660 species of reef fish are expected to occur in the waters of Pohnpei state, with 470 species recorded in 2005. The abundance of target species of reef fishes, particularly emperors, snappers, and groupers, appear to be low in many areas, possibly indicating local over-fishing.

Yap has more than 780 fish species in 76 families, although up to 900 total species may be present. The highly threatened humphead wrasse (*Cheilinus undulatus*) is relatively abundant (observed at 50% of survey sites) and the estimated average total length of individuals is only 48 cm. Few sharks were seen at Ngulu Atoll indicating probable shark finning.

**Guam:** Fish longer than 25 cm are uncommon to rare on Guam, and although their numbers are slightly higher on northern reefs, medium and large fish abundance is still very low compared to other islands in the Mariana Archipelago. Despite improvements in gear and technology, fishery catches on Guam have declined during recent decades. Small-scale fishery catches have declined by up to 86% since 1950 and data from DAWR creel surveys indicate that fisheries have not recovered from a sharp decline in the 1980s. Additionally, catches have continued to decline for hook and line and cast net methods, despite increasing effort. Large reef fish are noticeably absent from many reefs. The recent NOAA MARAMP towed diver surveys reports that the biomass of large reef fish (> 50 cm) is 5 times greater around remote islands in the southern Marianas, than around Guam and Santa Rosa Bank and 25 times greater in the more remote northern islands.

The use of scuba and artificial lights for spear fishing and the continued use of monofilament gill nets are particular concerns. These methods have been banned or heavily restricted in most Pacific countries but remain legal on Guam. Local fisheries biologists suggest these methods have contributed to a boom and bust harvest of large humphead wrasse, the depletion of large groupers, a shift from preferred species (large slow-growing fish) to smaller, faster growing species, and a decrease in the number of other large wrasse, parrotfish, snapper, and grouper caught by other methods. The government of Guam has created 5 Marine Preserves as a counter-measure, and fish biomass has increased significantly inside the preserves since enforcement began in 2001.



*Mean large fish (TL >50 cm) biomass (kg/ha) measured during towed-diver surveys in the Mariana Islands, Guam and the southern islands of the Northern Marianas, including Rota, Tinian, and Saipan. There are more large fish on the remote, and virtually unpopulated reefs than on the more heavily populated islands of Guam, Santa Rosa and to a lesser extent on the Southern islands (source Burdick et al., 2008).*

**Republic of the Marshall Islands:** Fisheries data is very limited and exploitation is unregulated, except that humphead wrasses are not permitted in atoll-to-atoll commerce. All non-destructive fishing techniques other than gillnetting (including night spearing with scuba) are currently allowed. No catch data or fish population statistics are collected and thus the extent of fish population status is unknown. Anecdotal observations suggest fish populations have declined on Majuro, Arno and other heavily populated atolls. The aquarium live fish trade is avidly pursued by 3 businesses which annually export tens of thousands of live fish, especially the prized flame angelfish, to Japan and America. Some fish populations are declining as there is no

geographic or numerical limit to the aquarium fish catch, although some businesses support the designation of no-take reserves to protect breeding stocks. Unfortunately, the Government regulatory process has stalled.

The illegal trade in shark fins still persists to supply Asian markets. An American operator is working to commercialize beche-de-mer fishing on Arno and elsewhere although they are not exploited on Majuro, where there are healthy populations. Tridacnid clams are widely harvested and *T. gigas* has become extremely rare. Some outer atolls still boast good *T. gigas* populations yet these remain vulnerable to illegal fishing. There are very few tridacnids near populated areas of Majuro, possibly due to heavy metal pollution interfering with recruitment. Green turtles are still harvested for subsistence purposes although it is illegal to sell any turtles or to take females that have come ashore. However, violations of these laws routinely occur and populations are likely dwindling.

### **CORAL REEF AND COASTAL RESOURCE MANAGEMENT**

**American Samoa:** The Department of Marine & Wildlife Resources (DMWR) has an on-going Community-Based Fisheries Management Program (CFMP) in 10 participating village MPAs, each with its own management plan. DMWR is also developing a network of no-take MPAs with a target to include 20% of the territory's coral reef ecosystems. The program is using biological criteria to identify unique and diverse coral reef habitats and areas found to have higher densities of recruits and spawning fish. DMWR is currently enforcing size limits on giant clams and lobsters as well as limits on mesh size for throw and barrier nets. Removing or damaging all coral is illegal, as are destructive fishing methods, and night time scuba spearfishing was banned in 2001. DMWR is currently adopting new regulations that will ban the taking of all large, rare reef fish species throughout the territory for all types of fishing gear (Box p. 209). The only permanent no-take area is Rose Atoll, a remote atoll that is a National Wildlife Refuge.

The National Park of American Samoa contracts with land owners, who agree to certain restrictions in return for monetary support; subsistence fishing, however, is allowed throughout the park areas and enforcement is lacking. The American Samoa EPA Piggery Compliance Team has recently reduced nutrient loads to nearby waters by more than 5000 kg of nitrogen and 1800 kg of phosphorous. One watershed saw a reduction in bacterial contamination by more than 90%. In collaboration with the Sanctuary's Advisory Council, local government partners and villagers, the Fagatele Bay National Marine Sanctuary (FBNMS) is reviewing the management plan to evaluate existing programs, identify emerging issues, and to address, enhance and strengthen future management. FBNMS is also exploring a site expansion of existing boundaries to promote greater recognition and protection. The leaders of Samoa and American Samoa have initiated the 'Two Samoas Initiative' to bring together local and regional environmental agencies and organizations to promote efficient management for addressing shared marine and terrestrial environmental concerns.

**Commonwealth of the Northern Mariana Islands:** The Commonwealth Utility Corporation is upgrading sewage treatment; chronic lagoon side sewer line overflows in San Antonio, Saipan have been eliminated. A repair project at Agingan Point Sewage Treatment Plant on Saipan will relocate an outfall, which presently empties directly into the sea at the waterline. Recent enforcements of bans on gill, drag and surround nets appears to be effective in conserving

fisheries resources within the Saipan Lagoon. Cast nets (talaya) are still legal with a permit and exemptions are issued for annual celebrations honouring village patron saints. Large nets are no longer used in CNMI, and conversations with local fishermen indicate an increased abundance and size of food fishes in the lagoon. CNMI is participating in the Micronesia Challenge and is focusing on marine resource status and pollution issues, along with consideration of local management efforts.

### AMERICAN SAMOA PROTECTS LARGE RARE REEF FISHES

American Samoa is moving to protect all of its large and rare reef fish from fishing, including humphead wrasses, bumphead parrotfish, giant grouper, giant trevally, and all shark species. These fishes will be protected throughout the territory, at all times, and for all sizes. The basis for protection is their rarity and possible local extinction if they continue to be exploited. The only information required for protection is that they are rare and exploited; thus it is much easier to establish the required protection rather than having to define over-fishing. Rare fish are rarely caught, so protection incurs little cost to fishers, thus opposition may be minimized. Some large fish have large ranges and cannot be protected adequately by small MPAs, so a ban throughout American Samoa will be more likely to be effective (Douglas Fenner, DMWR, douglasfenner@yahoo.com).

**Federated States of Micronesia:** The FSM completed a National Biodiversity Strategy and Action Plan in 2003 with a blueprint for conserving biodiversity and sustainably managing a full representation of the country's ecosystems. This identified 130 areas of biodiversity significance, including 86 coastal and marine sites comprising 260,948 ha. The FSM National Government and a number of local partners signed a National Implementation Support Partnership Agreement in 2004 pledging to collaborate and support the implementation of protected areas. Each State is developing protected area networks and Pohnpei has established 11 marine sanctuaries. Kosrae has begun developing an MPA program that involves co-management of coastal resources between local communities and state resource management agencies and 5 areas are actively managed by government agencies and/or local communities. Chuuk communities commenced conservation work in several areas, including the Parem Totiw Marine Area, the Wichap-Epinup-Peidiu-Nukanap Mangrove and Marine area, and the Polle Piannu Pass Grouper spawning area. In Yap, there is currently one Locally Managed Marine Area set up on Wa'ab by the Riken community. In addition, Yap CAP is assisting communities on Qokaaw and Kadaay on the Nimpal Channel and Maaq and Lebinaw on the Peelaek Channel.

**Guam:** Although there are no long-term coral monitoring data, various independent studies and assessments indicate significant declines in coral cover, coral diversity, coral recruitment, and reef fish stocks on Guam during the last few decades. With the exception of increased reef fish abundance within MPAs, low reef fish abundance around the island and poor nearshore water quality suggest that coral reef health on Guam is unlikely to improve in the next few years unless major management measures are implemented at local and global scales. The planned

military expansion and associated coastal development, combined with probable increases in coral bleaching, and the effects of ocean acidification increase the likelihood that coral reef health will continue to decline on Guam.

The Guam Coral Reef Initiative Coordinating Committee, along with numerous partners, is implementing projects to reduce the threats to Guam's coral reefs including outreach campaigns, MPA enforcement, and the development of a comprehensive monitoring strategy. Major public works, including the extension of sewage outfalls and the closing of Ordot dump, will also reduce reef stresses. Indications of increasing public awareness are evident in greater participation in cleanups and erosion control and more outreach and education activities. However, financial and human resources remain limited compared to the disproportionate value of goods and services generated by coral reefs. Present conservation capacity will be further stretched by the planned military expansion, and predicted increases in impacts from global climate change.

The total economic value of coral reef resources on Guam in 2005-2006 was between \$85-164 million per year, with a core value of US\$127 million/yr. Tourism revenue accounted for nearly 75% of this, while other non-consumptive uses, such as coastal protection, diving/snorkeling, and amenity value, each accounted for approximately 7%. The contribution of extractive uses like reef fisheries was almost negligible (3.1%) compared to non-extractive use values. Guam is also participating in the Micronesia Challenge.

**Republic of the Marshall Islands:** Pollution, subsistence and commercial fishing, and climate related stress continue to increase in the RMI. The high cost of transportation and continued increases in population numbers will cause increases in subsistence fishing. A new large-scale fish farm rearing humpback grouper and cobia will increase lagoonal nutrient loading. The abundance and diversity of corals on Majuro will continue to decline, as coral recruitment is suppressed by pollution and eutrophication. Reefs on outer atolls will continue to be pollution-free, however they remain a tempting target for the Asian live fish and shark-finning industries and are vulnerable to climate change impacts. The RMI lacks the capacity and budget to properly police and protect its outer atolls.

Coral dredging continues in the lagoon, representing the only commercial source of sand and aggregate, and small scale sand-mining continues on many beaches. Coastal erosion is ongoing and much of the southern lagoon shore of Majuro Atoll is composed of exposed bedrock where sandy beaches had previously occurred. The use of drag-line dredging was banned by RMI EPA in October 2008, to be replaced by suction dredging of deeper lagoon sediments.

A World Heritage workshop convened in Majuro in 2005 placed 9 atolls and one low reef island (Jemo) from the uninhabited northern Marshall Islands on a Tentative List. The nominations will be submitted to UNESCO in early 2009 to begin a formal evaluation by IUCN, ICOMOS and the World Heritage Commission within a two-year period. The national government also completed an action plan in early 2008 for the systematic protection of marine areas within the Republic.

## CONCLUSIONS AND RECOMMENDATIONS

**American Samoa:** Major disturbances have been produced by mass coral bleaching events, hurricanes, COTS and extreme low tide events, but the Territory's reefs appear to be amongst

the more resilient in the region. Piggeries, land development, and the lack of proper sewage treatment is an issue in certain areas. Coral reef fish populations, particularly around Tutuila, have low biomass and few large fish. Fishing effort and catch have declined over the past 30 years although there is likely a large unreported catch, particularly from night fishing activities. Fish populations on the outer banks and in deeper waters are in need of more extensive survey. An evaluation of the efficacy of the existing community-based fisheries management program is needed and a no-take MPA network needs to be implemented. Very little information is available on the impacts of habitat degradation on fish populations and fisheries. The issues of climate change and population pressure must be more effectively targeted with collaborative solutions. Enforcement and education/outreach continue to be two issues where more support is needed. Enhanced inclusion of cultural aspects and community participation in coral reef management will ensure increased compliance and effectiveness.

**Commonwealth of the Northern Mariana Islands:** CNMI's capacity to manage its coral reef resources effectively has grown substantially over the past 7 years as the ability to assess, monitor, educate and enforce coral reef management policy has grown through an increase in both personnel and the development of locally applicable management tools.

**Federated States of Micronesia:** Establishing new community-based marine protected areas for critical reef habitat will strengthen management and protection of coastal marine resources. Additionally, completing a gap assessment for areas of biodiversity significance, completing a capacity needs assessment for the protected area network, and determining baselines and developing indicators for measuring management effectiveness toward achieving the goals of the Micronesia Challenge will assist on-going management efforts.

**Guam:** Policy interventions must be prioritized in an economically sound manner to allocate the limited resources to effectively reduce coral reef degradation. Site-based approaches involving strong community participation and a coordinated network of multiple organizations will strengthen management to counter specific threats. Effective resource management will require more financial and staff capacity to reduce local coral reef threats and mitigate reef damage from stresses associated with climate change. The specific priority projects recommended for immediate implementation include: stop-gap measures to reduce soil erosion in southern Guam; large-scale restoration of southern watersheds; and an island-wide ban on monofilament gillnets and scuba spearfishing. A rapid, large-scale reduction in the pollution and over-fishing threats will enhance resilience to climate change impacts.

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#### LONG-TERM MONITORING IN AMERICAN SAMOA: THE AUA TRANSECT

Alfred Mayor of the Carnegie Institute in Washington DC established a transect in 1917 to study corals from the shore to the reef crest in the protected waters of Pago Pago harbor, near the village of Aua. The transect was covered by branching corals, with *Porites cylindrica* dominant from 15 m from shore to 160 m, and *Acropora* species dominant on the outer 100 m (30–75% cover). Substantial urban development began in Pago Pago after World War II and two tuna canneries were constructed in the 1950s, along with other developments. The inner 90 m of the 'Aua' transect was dredged for road construction which created a sediment plume over the transect for several years. The canneries poured out large volumes of wastewater which lowered water quality for 40 years (phosphorus concentration decreased by 80%, nitrogen by 75% and chlorophyll by more than 90% between 1990 and 1992). The Aua transect was resurveyed in 1973 by Art Dahl and Austin Lamberts who reported that the branching corals on the reef flat had converted into a blanket of loose rubble. In 1992 the canneries extended their outflows beyond the Aua transect where water flows were stronger. By 2000 coral cover was 2–10%, in 2004 it had increased to a mean of 31%. This was due to successful recruitment and growth on the solid bottom of the outer transect: live coral cover and species richness all increased to levels similar to those recorded by Mayor but with more, smaller coral colonies than in 1917. Coral cover today remains low on the inner reef flat where rubble predominates but the few colonies of *Acropora muricata* (= *A. formosa*), *Montipora*, *Millepora*, *Porites* and *Stylaraea* species appear healthy; cover on the outer flat ranges between 18% and 53%. The coral reefs of American Samoa are generally resilient and will recover readily from acute disturbances such as hurricanes, bleaching events and predation by COTS. The 90 year old Aua transect shows that chronic disturbances such as pollution can prevent coral growth for decades but the corals will bounce back if the disturbance stops; however, loose rubble will slow recovery until the bottom is stabilized (from Charles Birkeland, University of Hawai'i, [charlesb@Hawaii.edu](mailto:charlesb@Hawaii.edu)).

## 15. STATUS OF CORAL REEFS IN HAWAI‘I AND UNITED STATES PACIFIC REMOTE ISLAND AREAS (BAKER, HOWLAND, PALMYRA, KINGMAN, JARVIS, JOHNSTON, WAKE) IN 2008

ALAN FRIEDLANDER, JIM MARAGOS, RUSSELL BRAINARD, ATHLINE CLARK, GRETA AEBY, BRIAN BOWEN, ERIC BROWN, KATHY CHASTON, JEAN KENYON, CARL MEYER, PETRA MCGOWAN, JOYCE MILLER, TONY MONTGOMERY, ROBERT SCHROEDER, CELIA SMITH, PETER VROOM, WILLIAM WALSH, IVOR WILLIAMS, WENDY WILTSE AND JILL ZAMZOW

### ABSTRACT

#### *Hawaiian Archipelago*

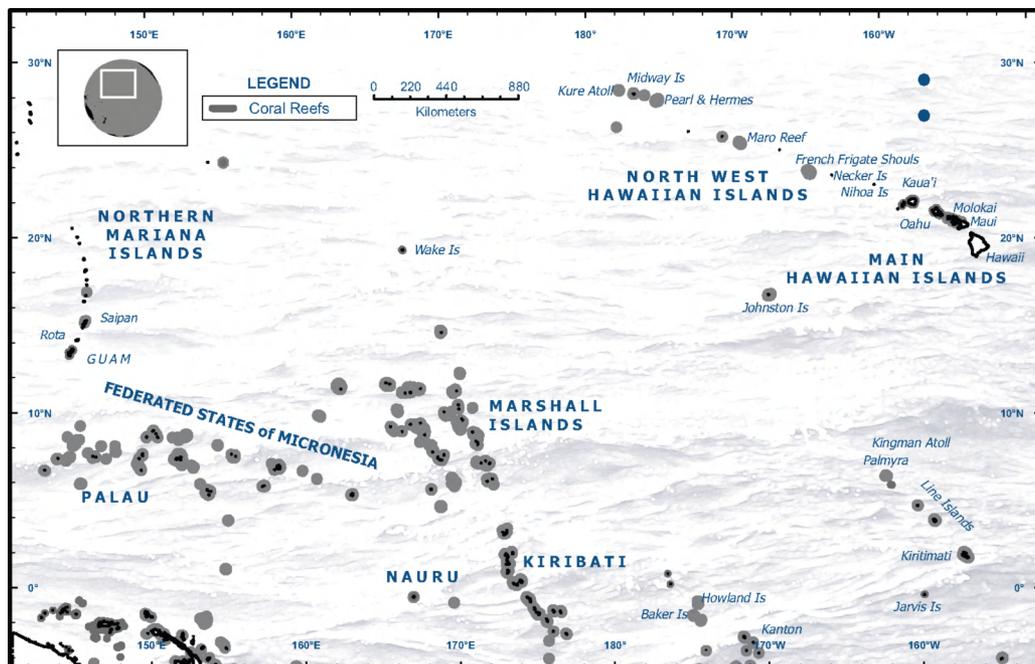
- Several urban areas and popular tourist destinations have suffered from pollution from the land, significant fishing pressure, recreational overuse, and alien species. Despite these pressures, many coral reefs in Hawai‘i remain in fair to good condition, especially remote reefs;
- Most MPAs have proven to be highly effective in conserving biodiversity and fisheries resources. MPA size, habitat quality, and level of protection are the most important success factors, but several MPAs are too small to have significant effects outside their boundaries;
- Community-based management has been effective at several locations in Hawai‘i and expansion of these efforts is being encouraged;
- Continued invasion and degradation of new habitats by alien species remains one of the most pressing threats to reefs in Hawai‘i;
- The Papahānaumokuākea Marine National Monument (PMNM) is the largest fully protected marine conservation area in the world, with a unique predator-dominated trophic structure, many endemic species, and many threatened and endangered species. This is an important global biodiversity ‘hot spot’;
- Global impacts such as climate change (sea level rise, ocean warming and acidification) and marine debris threaten the unique ecosystem of the PMNM, and rapid international action is needed.

## US Pacific Remote Island Areas (PRIAs)

- These are remote with limited human impacts, therefore they are nearly intact reefs with healthy coral communities, and predator-dominated fish assemblages with the highest fish biomass of all USA coral reefs (and near the highest recorded anywhere);
- Palmyra and Kingman are large atolls with higher coral biodiversity compared to other central Pacific islands: that may be due to being in the path of eastward flowing North Pacific Equatorial Countercurrent;
- Abandoned shipwrecks and associated fuel spills and degradation of reefs threatens these remote islands, including the rapid spread of an invasive corallimorph, *Rhodactis*, stimulated by dissolved iron at Palmyra and Baker;
- Residual World War II military construction and use continues to degrade habitats at Palmyra, Johnston, Wake, and Baker;
- The US Government is considering proposing the Central Pacific Islands Marine National Monument, which would create the world's largest MPA.

## INTRODUCTION

This chapter summarises the status of the coral reefs of the main Hawaiian Islands (MHI), Northwestern Hawaiian Islands (NWHI), and the US Pacific Remote Island Areas (PRIAs). The coral reef habitat shallower than 18 m encompasses 1595 km<sup>2</sup> in the NWHI, 1231 km<sup>2</sup> in MHI, and 252 km<sup>2</sup> within the PRIAs (Baker, 5 km<sup>2</sup>; Howland, 3 km<sup>2</sup>; Palmyra, 47 km<sup>2</sup>; Kingman, 21 km<sup>2</sup>; Jarvis, 3 km<sup>2</sup>; Johnson, 150 km<sup>2</sup>; Wake, 23 km<sup>2</sup>). Complete details for each area appear in *The State of Coral Reef Ecosystems of the United States and Pacific Freely Associated States (SCRE): 2008* (<http://ccma.nos.noaa.gov/stateofthereefs>).



**Hawai'i:** The Hawaiian Archipelago spans over 2500 km from the island of Hawai'i in the south-east to Kure Atoll (the world's highest latitude atoll) in the north-west. These coral reefs in the central Pacific Ocean are exposed to large open ocean swells and strong trade winds that result in distinctive reef communities. The geographic isolation of Hawai'i has resulted in some of the highest endemism of any tropical marine ecosystem on earth. The archipelago consists of two regions: the populated main Hawaiian Islands (MHI); and the mostly uninhabited atolls, islands, and banks of the Northwestern Hawaiian Islands (NWHI). There are 8 high volcanic islands in the MHI, ranging in age from active lava flows on Hawai'i Island to Ni'ihau, formed 5.6 million years ago. The NWHI represent the older portion of the emergent Hawaiian Archipelago, beginning at Nihoa (7 mya) and extending to Midway and Kure Atolls (28 mya). The NWHI reefs are remote, nearly pristine and represent one of the last remaining intact large-scale predator-dominated coral reef ecosystems.

Coral reefs were important to the ancient Hawaiians for subsistence, culture, and survival and today provide commercial, recreational and subsistence fishing opportunities, world famous surfing and diving locations, and contribute US\$800 million a year from marine tourism industry to the State's economy. The full economic value of Hawai'i's coral reefs was estimated at US\$10 billion, with direct economic benefits of \$360 million per year in 2002. However, several urban areas and popular tourist destinations have suffered from land-based sources of pollution, significant fishing pressure, recreational overuse, alien species, and coastal construction. Despite these human pressures, many of Hawai'i's coral reefs in remote areas are still in fair to good condition.

**PRIAs:** Pacific Remote Island Areas (PRIAs) are isolated US sovereign islands and atolls outside the jurisdiction of any specific State or Territory. The 7 islands and atolls are dispersed over a vast and remote area in the central Pacific Ocean and influenced by varying oceanographic and climatic conditions and processes; 6 of these are National Wildlife Refuges (NWR) under the jurisdiction of the US Fish and Wildlife Service (USFWS). Wake Atoll, the only one that is not a refuge, is under the control of the Department of the Interior and operated by the US Air Force, with a population of 150-250 Air Force personnel and contractors. The coral reefs of the PRIAs remain quite healthy and productive, with few impacts from unauthorized fishing, abandoned WWII materiel, and residual effects from guano mining, ship groundings, and climate change. These islands experience occasional tropical storms.

### **MAIN HAWAIIAN ISLANDS – STATUS OF CORAL REEFS IN 2008**

Monitoring of Hawaiian coral reefs started in the 1960s and has documented numerous changes. Some communities are monitoring and managing their local resources in addition to State, Federal, university, non-profit, and NGO programs. Sediment is the leading land-based pollutant and is increasing as coastal areas are developed for agriculture and urban growth, including filling of floodplains, construction of storm drains, and stream channelisation. Most of the sewage treatment plants discharge secondary treated wastewater into the ground through 15–60 m deep injection wells. A recent tracer study on Maui identified the plume from such wells entering adjacent nearshore waters causing local overgrowth of marine algae near some popular beach areas.

The average annual sea surface temperatures (SSTs) in Hawai'i have increased 0.8°C since 1956; but there have only been 3 documented major bleaching events within the Hawaiian

Archipelago (MHI 1996, NWHI 2002 and 2004). Surveys in 2004 and 2005 revealed the presence of 8 coral diseases in the 3 major coral genera (*Porites*, *Montipora*, *Pocillopora*), but generally disease prevalence was low.

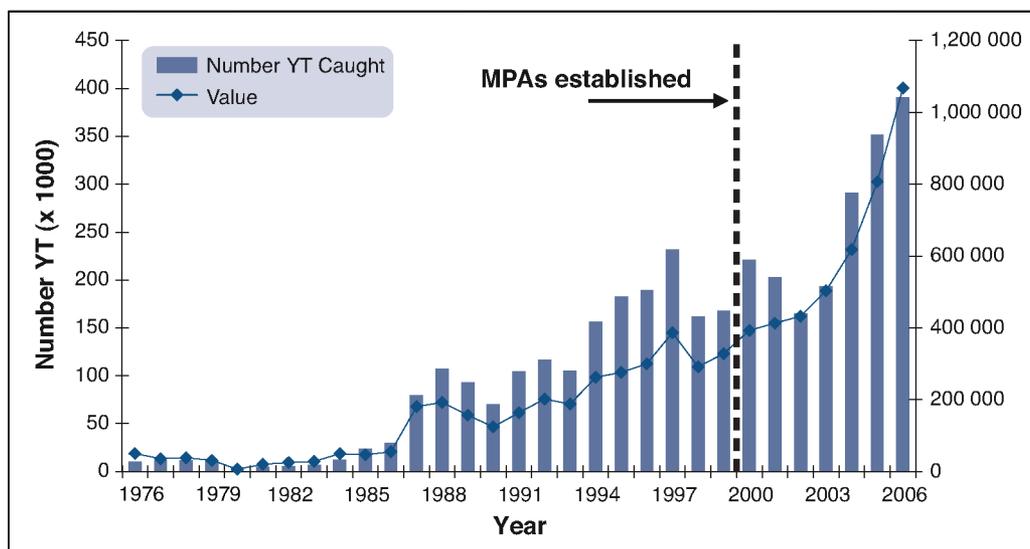
Most coastal waters are generally in good condition, but no comprehensive water quality monitoring program currently exists. Storm water runoff during high rain events cause many beaches to close for human health and safety reasons. A very large spill of more than 18 million litres of untreated wastewater occurred on March 24, 2006 into the Ala Wai canal and nearby Waikiki. The Hawai'i Department of Health 2006 list of polluted waters contains 93 streams and 219 coastal areas. The problem coastal waters are primarily harbours, semi-enclosed bays and protected shorelines, where mixing is reduced and resident time of pollutants is long compared to exposed coasts.

Coral cover across the MHI at 1682 sites averaged 19.9% with 7 coral species accounting for 96% of the total. Coral cover of hard-bottom habitats was highest in the southern portion of the MHI (Molokini, 45% and Kahoolawe, 49%) and lowest in the northern part (Ni'ihau, 4%). In general, coral cover decreased with increasing geologic age (i.e. from south-east to north-west;  $R = -0.73$ ). Coral cover at 27 long-term (more than 10 years) monitoring sites showed that cover at 70% of the sites had declined since monitoring started, with an average decline of 8%. Coral cover at 10 sites monitored for more than 30 years has declined by an average of 12%.

An assessment of 55 fish stocks in the MHI showed that 75% of the stocks examined were below typical over-fishing thresholds (25% of virgin stock biomass). Fish biomass data compiled from 6 comprehensive studies at 188 locations ( $n = 1427$  transects) was negatively correlated with human population density by island ( $R = -0.89$ ). The remote island of Ni'ihau had the highest fish biomass while Oahu, with 72% of the state's population, had the lowest overall fish biomass among the MHI. At Oahu, apex predators were virtually absent, likely due to intense fishing pressure.

Alien species, particularly algae, continue to damage many nearshore marine environments around the MHI. The Hawai'i Marine Algae group (HIMAG) and interested community groups have developed methods to manage invasive species, especially algae. Since 2002, communities have removed over 150 tons of invasive algae in clean-up events with more than 2550 volunteers. HIMAG developed the 'super sucker,' an underwater vacuum, to remove large amounts of alien marine algae, especially in efforts to restore native reef habitats in Kane'ohe Bay. The invasive soft coral, *Carijoa*, has spread over deeper reef areas and smothered some stands of black corals.

**Socioeconomics:** More than 82% of Hawai'i's tourists participate in some form of ocean recreation, generating almost \$364 million each year; and 66% of 1600 local households surveyed participated in ocean swimming (28 times per year between 2004 and 2005). Other major uses of the coasts included recreational fishing (31% of households, 10 times per year), surfing (29% of households, 18 times per year), snorkelling (32% of households, 6 times per year) and subsistence fishing (10% of households, 5 times per year). The involvement of ethnic Hawaiians in ocean activities was 10–20% higher than other groups.



*The number and value of yellow tang, the main aquarium target fish, caught in the west Hawai'i aquarium fishery from 1976 to 2006 has increased dramatically since 1987 and also since MPAs were established in 2000 (source: DLNR/DAR).*

**Status of Fisheries:** Hawai'i's coastal fisheries resources are shared by subsistence, recreational, and small-scale commercial fishers. Seine nets have the highest catch rates per trip, followed by set gill nets, spear fishing, and handlines. The average catch per trip by seine nets, excluding coastal pelagic species, declined by 35% from 1966 to 2006: the catch also changed from jacks, bonefish, and threadfin being the dominant target species, to less valuable surgeonfishes and goatfishes. Total catch by handlines has also declined since the early 1990s; however the catch by spearfishing has increased during this same time. The Hawai'i Marine Recreational Fishing Survey in 2006 showed the recreational catch was dominated by goatfishes, surgeonfishes, and jacks (sampling limitations reduced the confidence in numeric estimates).

The commercial aquarium fishery is now Hawai'i's major inshore fishery, with landings reported as more than 990 000 specimens, valued for collectors at US\$1.93 million in 2006 (75.6% coming from the island of Hawai'i). In 2000, 9 Fish Replenishment Areas (FRAs) which prohibit aquarium collecting were established in West Hawai'i to conserve aquarium reef fishes and reduce conflict among resource users. These FRAs cover 35.2% of the West Hawai'i coastline and designations were based on substantial community input. Despite this reduction in aquarium collecting area, there are now many more collectors, and the total number of fish caught and their value have approximately doubled to that prior to the creation of the FRAs. Aquarium fish density has increased in the FRAs, especially the density of the primary target species (yellow tang, *Zebrasoma flavescens*). This indicates that FRAs are effective at replenishing aquarium fish stocks in West Hawai'i after 7 years. Total fish biomass and the number of large fishes (>20 cm) was greater in 12 MPAs than in adjacent areas open to fishing by more than 200% and 150%, respectively.

**Conclusions and Recommendations:** Food, recreation, culture, commerce, aesthetics, and shoreline protection are a few of the ecosystem services provided by Hawai'i's coral reefs. These reefs also have extremely high biodiversity and conservation value due to large proportions of endemic species. The coral reefs are valued at more than US\$10 billion, thus are an important component of the economy especially for leisure pursuits and the Hawaiian way of life. However, the 1.2 million residents (70% live on Oahu) and more than 7 million tourists visit each year put increasing pressures on Hawai'i's coral reefs.

As coastal development continues to expand in the MHI, focus should be given to the implementation, maintenance, and enforcement of best management practices that reduce sediment runoff and prevent further damage to coral reefs. Management should be ecosystem-based to include the entire watershed from ridge to reef. The continued invasion and damage by alien species remains a major threat to Hawai'i's reefs and mechanical and hand removal of invading algae has proven to be effective at a small scale: large scale removal should be implemented.

The effects of intensive fishing pressure must be mitigated and stocks and ecosystems rebuilt through co-ordinated measures including: increasing restrictions on very efficient fishing gear such as gillnets and scuba fishing (particularly at night); bag limits; and larger closed areas. For example, in 2006 set (lay) nets were banned around Maui and parts of Oahu, and now all lay nets must be registered with limits on mesh size, times and location. There are no recreational fishing licenses in Hawai'i and the non-commercial catch is enormous, therefore more emphasis is needed to assess these fisheries and manage them.

MPAs are highly successful in Hawai'i at conserving biodiversity and fish resources, as well as increasing fish yields nearby, such as aquarium fish. However, less than 1% of the reefs around the MHI are in no-take MPAs: increasing the number and size of MPAs in Hawai'i will greatly improve fish stocks and help preserve biodiversity.

A network of more than 28 communities meets twice a year to discuss local resource management issues. In some areas, community planning and active participation in management is a direct response to growing concerns about over use of resources or perceived changes to lifestyle. Locally-managed marine areas that incorporate traditional concepts of customary marine stewardship into MPA management are helping to increase the effectiveness of decision making and helping with rules and regulations compliance. An ecosystem-based management will require comprehensive ocean zoning to resolve the mismatches between the spatial and temporal scales of governance and ecosystems.

## **NORTHWESTERN HAWAIIAN ISLANDS – STATUS OF CORAL REEFS 2008**

In 2006, the Government of USA designated the Northwestern Hawaiian Islands Marine National Monument (later renamed Papahānaumokuākea Marine National Monument, PMNM) as one of the world's largest conservation areas (362 600 km<sup>2</sup>). The management of the PMNM is shared by 3 co-trustee agencies: State of Hawai'i; United States Department of the Interior, Fish and Wildlife Service; and Department of Commerce, NOAA. A number of government and non-government organizations conduct research and monitoring of the coral reefs in the NWHI. Scientific expeditions in the NWHI since 2000 have reported many new records and some new

species. For example, a coral species cannot be identified to the genus or family level, so it may be a relic (or 'fossil') species. The live coral cover on the islands and atolls ranged from <1% at Gardner Pinnacles to 37% at Lisianski-Neva Shoal (average 19.9%). There was no significant difference in coral cover at 27 permanent stations in 2000–2002 (16.6%) and 2006 (14.0%;  $p>0.05$ ). Cover of macroalgae, turf algae, crustose coralline algae and coral populations at 8 US islands across the Pacific, showed that the NWHI have the highest algal cover and the lowest coral cover. This is probably due to the subtropical location of the NWHI where there are often cool water temperatures and a high frequency of large waves during winter.

The prevalence of coral disease is low in the NWHI; 10 diseases have been reported affecting the 4 major genera (*Porites*, *Montipora*, *Pocillopora*, *Acropora*) with *Porites trematodiasis* disease being the most common. Levels of disease appear to be stable through time, with the exception of *Acropora* white syndrome at French Frigate Shoals. This disease kills *Acropora* and there was partial to total mortality in 97.6% of the 41 marked colonies after one year. Only 5 introduced invertebrate species have been found in the NWHI; much less than the 287 introduced species in the MHI.

Total fish biomass assessed in 2000–2002 (1400 kg per hectare) did not differ significantly ( $p>0.05$ ) from estimates made in 2005 (1200 kg per hectare) and there were no differences in the fish trophic structure. Apex predators accounted for 36% of total biomass, followed by herbivores (34%), secondary carnivores (24%), and plankton eaters (6%); 55% of the total biomass on the fore-reef was apex predators, with a lower proportion in sheltered sites where there are usually fewer predators.

The NOAA Coral Reef Conservation Program and Marine Debris Program, and the Pacific Islands Fisheries Science Center removed 511 tons of historical debris from the reefs of the NWHI between 2001 and 2005. It is estimated that the annual accumulation rate of debris is more than 52 tons, which indicates that the current level of removal is not sufficient to keep up with accumulation. More effort will be required to negotiate with potential East Asian source countries for a reduction of debris, especially abandoned fishing nets.

There are contrasting trends with endangered megafauna in the NWHI; the Hawaiian monk seal (*Monachus schauinslandi*) is the only endangered pinniped entirely within US waters and the only seal dependent on coral reefs. The current population is about 1100 seals, a decrease of about 60% since the 1950s. Counts declined by 5% per year from 1985 to 1993, were relatively stable through 2000 and have declined after 2001, with lowest abundance recorded in 2005. The Hawaiian green turtle population is a single genetic stock that is endemic to the Hawaiian Archipelago. The principal rookery is at French Frigate Shoals where more than 90% of all nesting occurs. When protection and management started in the 1970s, the green turtle population was about 20% of pre-exploitation stock; now it is estimated to be about 83% of pre-exploitation stock with a population growth of approximately 5.4% per year. However, the critical nesting beaches on Eastern Island, French Frigate Shoals continue to shrink due to local sea level rise and heavy wave action. Similarly, the beach habitat for the Hawaiian monk seal is also declining in the NWHI.

**Status of Fisheries:** Recent fishing and other resource extraction in the NWHI has been mostly limited to two commercial fisheries: the on-going NWHI bottom fish fishery; and the now-closed NWHI lobster trap fishery. All fishing activity in the NWHI is declining with the designation of the PMNM. The bottom fishery can continue until mid-2011, and current monitoring will provide crucial information on the abundance and distribution of target species for management of stocks in the MHI. There is no trade in coral and live fish in the PMNM.

**Conclusions and recommendations:** The NWHI is one of the few regions in the world where monitoring and research can be conducted in virtual absence of human pressures. This allows extrapolations about subtropical reefs in the past, and what might occur in the future if larger and more effective no-take marine reserves were to be established elsewhere. The co-trustees of the PMNM are committed to preserving the ecological integrity of the monument and perpetuation of NWHI ecosystems, native Hawaiian culture, and other historic resources. The final regulations for the PMNM spell out the management scope and purpose, boundary, definitions, prohibitions and regulated activities. The co-trustees developed and signed a Memorandum of Agreement in 2006 to establish roles and responsibilities, and co-ordination bodies and mechanisms for management; as well as developing a research plan to provide direction for future research in the NWHI. The most pressing management concern in the NWHI is the introduction of alien and invasive species; thus the Aquatic Invasive Species Response Team at the State of Hawai'i Division of Aquatic Resources has recently started inspecting the hulls of all vessels travelling to the NWHI from the MHI to prevent or reduce the introduction of alien species. Another management recommendation is to increase marine debris removal at local and international levels.

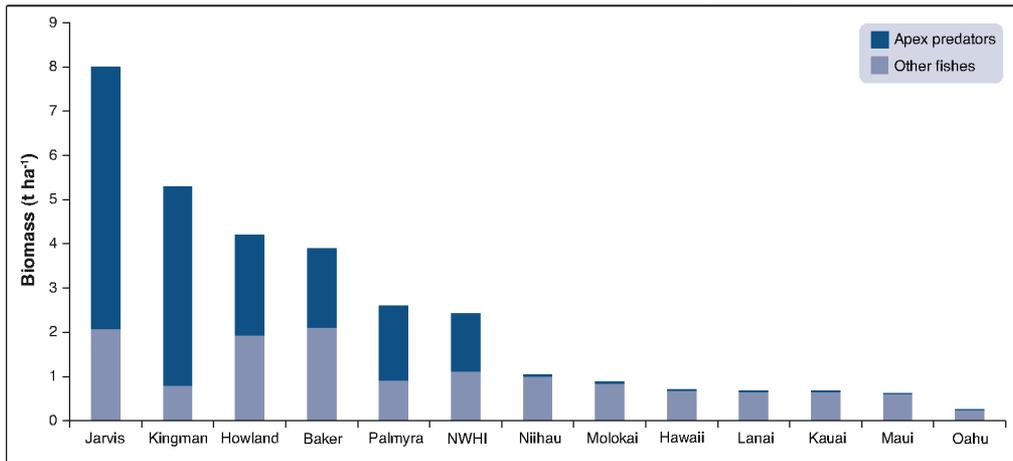
### **PACIFIC REMOTE ISLAND AREAS (PRIAS): STATUS OF CORAL REEFS 2008**

To survey these remote US Pacific Island Areas requires large vessels and interagency collaboration. NOAA has conducted biennial Pacific Rapid Assessment and Monitoring Program (RAMP) cruises since 2000 at all 7 locations with scientists from the Pacific Islands Fisheries Science Center's Coral Reef Ecosystem Division (PIFSC-CRED), the USFWS, and collaborating institutions. The Scripps Institution of Oceanography (SIO) also sponsored surveys at Palmyra and Kingman in August 2005, Palmyra in August 2006 and Kingman in August 2007. The PRIAs are part of 3 central Pacific archipelagos: Wake Atoll at the north end of the Marshall Islands; Baker and Howland Islands at the north end of the Phoenix Islands; Johnston Atoll, Kingman Reef and Palmyra Atoll at the north end, and Jarvis Island at the middle, of the Line Islands. In 2006 tropical cyclone Ioke, one of the strongest storms seen in the Central Pacific, struck Johnston Atoll as a Category 2 hurricane and Wake Atoll as a Category 4 typhoon.

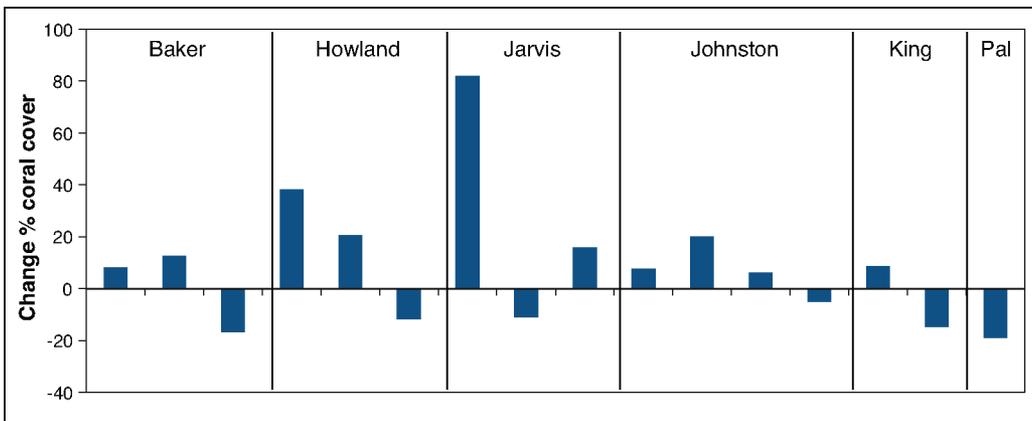
Although there are 264 total species in 52 hard coral genera and 22 other cnidarian genera reported in the PRIAs, the individual totals range from 50 species and 20 genera at Jarvis and Johnston to approximately 190 species and 50 genera at Kingman and Palmyra. These numbers are consistent with other Central Pacific reefs and reflect the role of habitat size, diversity, proximity to neighbouring reefs in determining the diversity at each reef. Two of the largest atolls (Palmyra and Kingman) have substantially higher coral diversity compared to Kanton, Tabuaeran and Kiritimati Atolls and may benefit from the North Pacific Countercurrent which carries larvae of species from the western Pacific where there are many more species. There has not been any recent severe or chronic coral bleaching at the PRIAs to date, probably because these reefs are in a healthy and resilient state; Palmyra may be an exception due to lagoon

degradation from WWII military construction. Live coral cover of more than 40% is common in protected, leeward, and lagoon habitats, whereas coral cover generally does not exceed 20% in wave-exposed habitats. Recent towed-diver surveys showed that cover of hard and soft corals combined was highest on Palmyra (44%), followed by Kingman (41%), Baker (38%), Howland (36%), Jarvis (24%), Johnston (25%), and Wake (28%).

Coral cover at 16 selected permanently marked transect sites, representing 7 of the PRIAs (except Wake), has increased at 10 sites and decreased at 6 sites between 2000 and 2008 in all PRIAs, with first measures of mean coral cover being 36% and latest surveys at 48%. This



*This graph clearly shows the difference in fish biomass, especially for apex predators, between the remote US Pacific Remote Island Areas (left, Jarvis to Palmyra), the Northwestern Hawaiian Islands and the main Hawaiian Islands (right, Niihau to Oahu) with almost no apex predators in the last 7 island reefs.*



*This figure summarises changes in percent cover of corals and other cnidarians between the earliest and latest surveys at 16 permanent transect sites in the 6 US Line & Phoenix Islands National Wildlife Refuges between 2000-2008. Coral cover has increased at 10 sites, and decreased at 6 sites (Pal = Palmyra).*

overall increasing trend is probably due to coral recovery after bleaching in the late 1990s. Coral declines at the boat anchorages at Baker and Howland appear to be due to competition between corals and invasive blue-green algae, stimulated by dissolved iron from wrecks and other scrap metal. A decline at Jarvis may be from wave damage, and declines in *Acropora* species at Johnston are likely related to coral diseases and residual damage from military construction. Coral declines at one Kingman site are related to crown-of-thorn starfish (COTS, *Acanthaster planci*) predation, but the high abundance of prey corals elsewhere around Kingman indicates that these are serving to maintain COTS at high levels since 2002; this is not reported on less healthy reefs. *Acropora* corals are a sensitive indicator of environmental stress: because they continue to flourish on many PRIA sites, it shows that coral populations are predominantly in excellent condition. There are about 200 species of turf and macroalgae in the PRIAs; the Line Islands (Palmyra, Kingman, and Jarvis) have higher algal diversity than the Phoenix Islands (Howland and Baker) despite being similar in size.

Surveys in 2006 indicate that the overall prevalence of coral disease across the region is very low compared to reefs near populated areas, affecting between 0.01 and 2.8% of colonies at the 80 survey sites; 39 sites (48.8%) showed some disease, with Johnston Atoll (a former military base) having the highest occurrence of coral disease (at 78% of sites) and the highest mean prevalence ( $0.7 \pm 0.2\%$ ; mean  $\pm$  SE).

The abundance of reef sharks, large groupers, jacks, and humphead wrasses are much higher on the PRIA reefs than on other reefs in the region where there has been fishing pressure. These reefs are among the most predator-dominated and biomass-rich reefs and atolls in the Pacific. Fish assemblages at Howland, Baker, Palmyra, Kingman, and especially Jarvis rank among the highest biomass (3000–8000 kg/ha) and most predator-dominated (54–74%) reefs ever surveyed.

Commercial fishing has been prohibited within the Natural Wildlife Refuges by the government but the NOAA Fisheries Pacific Regional Office issues commercial bottom fishing and lobster fishing permits in the PRIAs. Some unauthorized fishing within NWR boundaries is suspected at several PRIAs where surveillance and monitoring efforts are presently inadequate.

**Conclusions and Recommendations:** The PRIA reefs represent some of the most intact and healthy ecosystems remaining anywhere with high biodiversity, coral cover and reef fish biomass, as well as predator-dominance. These reefs provide a unique opportunity to examine and understand ecosystem function and resilience to climate change in the absence of direct human impacts. Thus they deserve the highest levels of protection and conservation. Most of the islands are uninhabited with no coastal development and runoff, however, there are residual impacts from military use on Johnston, Palmyra and Wake Atolls and Baker Island. An emerging threat is the potential for increased commercial fishing, especially illegal, unauthorized and unreported shark finning and bottom and lobster fishing, mostly by foreign fishers on uninhabited reefs.

Palmyra was purchased by The Nature Conservancy in 2000 and the USFWS purchased all of Palmyra from TNC in 2001 except for the main island (Cooper) to establish the Palmyra Atoll NWR. Now the USFWS oversees conservation management and research in cooperation with TNC, which manages the research station on Cooper Island constructed by TNC in 2006.

Members of the research consortium include Stanford University; SIO; American Museum of Natural History; California Academy of Sciences; the University of California at Santa Barbara and Irvine; University of Hawai'i; US Geological Survey; TNC; and Victoria University of Wellington, New Zealand. The station cost \$1.5 million and is funded by the Gordon and Betty Moore Foundation for up to 20 researchers. These National Wildlife Refuges will help protect against human impacts, and the new proposed Marine National Monument covering all 7 PRIAs could result in reducing commercial fishing inside refuge boundaries, and provide improve surveillance, enforcement, removal of existing shipwrecks at Kingman, Palmyra and possibly Wake, and support for other restoration initiatives in the ocean and on land, at Kingman, Palmyra, Baker, Johnston and Wake.

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### PAPAHĀNAUMOKUĀKEA MARINE NATIONAL MONUMENT

On June 15, 2006, the President of the USA, George W. Bush designated the Northwestern Hawaiian Islands (NWHI) as a Marine National Monument, one of the world's largest conservation areas. The Monument encompasses nearly 362,600 km<sup>2</sup> of ocean and includes all the islands, atolls, shoals and banks from Nihoa Island to Kure Atoll. In March 2007, the NWHI was renamed as the Papahānaumokuākea Marine National Monument (PMNM) by the President's wife, Laura Bush. Native Hawaiians consider the NWHI as a sacred place where life begins and spirits return after death.

The unique predator-dominated trophic structure, the large numbers of endemic species, and the occurrence of threatened and endangered species makes the PMNM an ecosystem of global significance. These reefs and islands offer a rare glimpse into how a large-scale coral reef ecosystem should appear and function without damaging human impacts. The region contains the critically endangered Hawaiian monk seal (Box p. 24), contains one of the largest and most important assemblages of seabirds in the world, and supports 90% of sea turtles found in the whole Hawaiian Archipelago. Approximately 25% of all species examined are endemic to the Hawaiian Archipelago making this region an important biodiversity 'hot spot'.

Management of the PMNM is the responsibility of the State of Hawai'i, the United States Department of the Interior, Fish and Wildlife Service, and the Department of Commerce, NOAA: these co-trustees are committed to preserving the ecological integrity and perpetuation of the ecosystems, native Hawaiian culture, and other historic resources. Management of the PMNM will be comprehensive and based on integrated ecosystem-based management that seeks to conserve this valuable and irreplaceable ecosystem well into the future via an integrated management structure that ensures continued co-operation among all partners. The most significant long-term threats will be from diseases, ocean acidification, sea level rise and bleaching associated with climate change. The large number of endemic species and the unique ecosystem dynamics make the region particularly susceptible to alien and invasive species. Also, this area is increasingly susceptible to poaching from the many distant-water fishing fleets, and enforcement will require improved surveillance technologies.

The PMNM will serve as a key sentinel for monitoring and deciphering short- and long-term responses to local, regional, and global environmental and human stressors because it is remote, uninhabited, and relatively pristine compared to other reefs in the world. On-going research, monitoring, habitat restoration and conservation management of the PMNM will provide significant insights to benefit management for all islands and coral reefs. The PMNM represents a natural and cultural treasure of high scientific, conservation and aesthetic value, and the wise stewardship of this unique ecosystem is the responsibility of us all (from Alan Friedlander [alan.friedlander@noaa.gov](mailto:alan.friedlander@noaa.gov)).

# 16. STATUS OF THE CORAL REEF ECOSYSTEMS IN THE U.S. CARIBBEAN AND GULF OF MEXICO: FLORIDA, FLOWER GARDEN BANKS, PUERTO RICO, NAVASSA AND USVI

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## INTRODUCTION

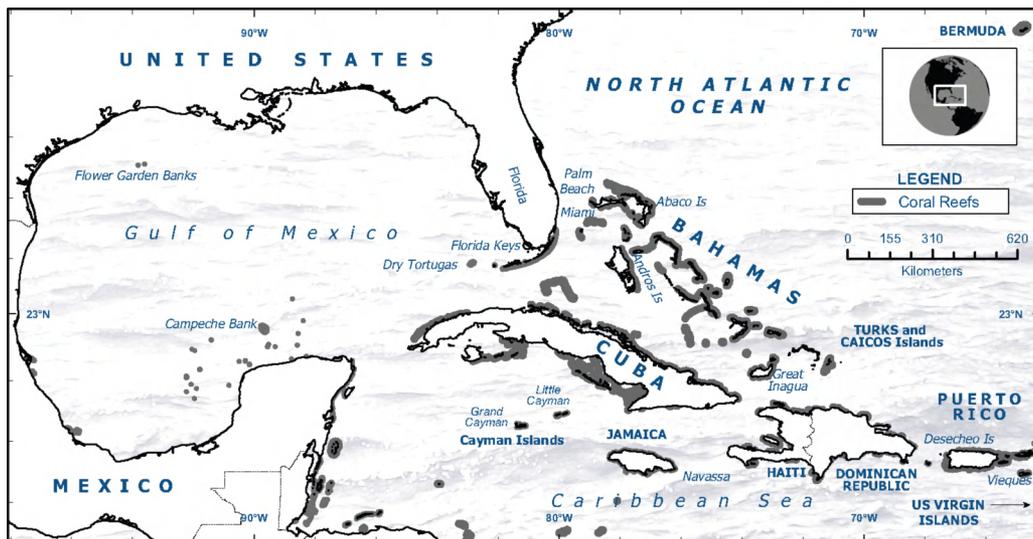
This chapter covers coral reef areas under the jurisdiction of the USA in the Wider Caribbean: Florida; Flower Garden Banks; Puerto Rico; U.S. Virgin Islands; and Navassa. The following information is condensed from six chapters of *The State of Coral Reef Ecosystems of the United States and Pacific Freely Associated States: 2008*. Access to the full text of this comprehensive report is available at: <http://ccma.nos.noaa.gov/stateofthereefs>.

**Southeast Florida:** The northern extension of the Florida reef tract and a complex of limestone ridges run 170 km parallel to the coast of southeast Florida, from Biscayne National Park in Miami-Dade County to the St. Lucie Inlet in Martin County. The reefs and hard bottom areas support rich and diverse biological communities. Nearshore reef habitats include hardbottom areas, patch reefs and worm reefs (*Phragmatopoma* spp.) with abundant octocoral, macroalgae, stony coral and sponge assemblages. Offshore reef assemblages grow on an old Holocene

*Acropora palmata* mid-shelf and shelf margin reefs extending from Miami-Dade County to Palm Beach County. The reefs from Palm Beach County to Martin County grow on Anastasia Formation limestone ridges and terraces. Southeast Florida is highly developed with more than 5 million people living close to the coast; many of the reefs are within 1.5 km of that coast. These are the highest latitude reefs on the western Atlantic coastline, but until recently, they received limited scientific and resource management attention.

**Florida Keys:** These form a 378 km island archipelago from Biscayne Bay to the Dry Tortugas, where the waters and climate are strongly affected by the Florida Current which brings juveniles and larvae of various marine organisms to the reefs. Parallel to the islands is the Florida reef tract consisting of almost continuous banks from Fowey Rock near Soldier Key to the Dry Tortugas. These islands and reefs are in the Florida Keys National Marine Sanctuary (FKNMS) and the Biscayne and Dry Tortugas National Parks. The FKNMS covers 9850 km<sup>2</sup> and includes coral reef and hard bottom habitats. The Dry Tortugas National Park covers 259 km<sup>2</sup>, includes 7 small islands totaling 0.4 km<sup>2</sup> in area. The Tortugas Banks are a massive complex of submerged reefs on Pleistocene Karst limestone at depths of 21-27 m, with high coral cover but low coral diversity. The most conspicuous coral is *Montastraea cavernosa*, and the black coral (*Antipatharia* spp.) is abundant on the outer bank edges. There is a major fishery for groupers and snappers throughout the Florida Keys.

**Flower Garden Banks National Marine Sanctuary:** A network of banks and other submarine geologic features occur along the edge of the continental shelf south of Texas and Louisiana in the northwestern Gulf of Mexico. The banks are uplifted salt domes of Jurassic origin, rising from more than 100 m to 17 m of the surface, and some support thriving coral communities. Two of the banks, the East and West Flower Garden Banks (EFGB and WFGB), were designated as the Flower Garden Banks National Marine Sanctuary (FGBNMS) through the National Oceanic and Atmospheric Administration (NOAA) in January 1992. Stetson Bank was added to the FGBNMS in 1996, bringing the total area of the sanctuary to 145.8 km<sup>2</sup>.



**U.S. Virgin Islands:** The USVI contains mosaics of coral reefs, seagrass beds, mangroves, sand and algal flats around the main islands of St. Thomas, St. John and St. Croix, and more than 60 smaller outlying cays. It is estimated that the reefs could cover 2,126 km<sup>2</sup>, but only a small proportion of the deeper reefs have been mapped. The shallow reefs (<18 m) are estimated to cover approximately 344 km<sup>2</sup>. As biologically rich ecosystems, they provide important goods and services to the islands in the form of shoreline protection, fishing and tourism. However, USVI coral reefs have been damaged by human activities; in response, additional fishing regulations have been enacted and MPAs designated or increased in size (see map p. 240).

**Puerto Rico:** The Commonwealth of Puerto Rico comprises the main island of Puerto Rico plus Culebra, Vieques, Monito, and Desecheo offshore islands in the northern Caribbean. Surrounding the islands and cays are a complex mosaic of coral reefs, seagrass beds and mangrove forests. There are also deep coral formations, including the 'Deep Terrace', 'Drop-off Wall' and 'Rhodolith' reefs down to 90 m depth. These are critical habitats for fish and invertebrates.

**Navassa:** This is a small (4.64 km<sup>2</sup>), uninhabited, oceanic island approximately 50 km southwest of Haiti under the jurisdiction of the U.S. Fish and Wildlife Service. It is a raised dolomite plateau with vertical cliffs that descend to a sloping submarine terrace at about 25 m depth, with coral growing primarily on small nearshore ledges and shelves. The open ocean position of Navassa in the Windward Passage exposes it to persistent swells, especially on the eastern side, and regular storms and hurricanes.

## STATUS OF THE CORAL REEFS IN 2008

**Southeast Florida:** The reefs of southeast Florida generally have low coral species richness and high cover of octocorals, sponges and macroalgae. The Southeast Florida Coral Reef Evaluation and Monitoring Project reports little change in the status of the southeast Florida reef system between 2003 and 2006. There has been no trend in stony coral species richness at the 10 sites sampled since 2003, except at the nearshore site in Palm Beach County, which was partially covered in sand in 2005 and 2006. There is a trend towards reduced coral species richness to the north with Miami-Dade County having 21 species and Broward County 24 species, while Palm Beach County has 17 and Martin County has 8 species. The most common stony corals in all counties are *Montastraea cavernosa*, *Siderastrea siderea* and *Porites astreoides*. Octocorals consistently contribute most to the bottom biota cover in Miami-Dade, Broward and Palm Beach Counties followed by macroalgae and sponges; while macroalgae dominate in Martin County. Total stony coral cover is generally between 0.5% and 2.5%, however, two nearshore monitoring sites in Broward County have 13% and 39% coral cover. The Broward County Marine Biological Monitoring Program reports coral cover and mean octocoral density have not changed significantly since 2001 at 23 sites, and multivariate statistical analysis shows that stony coral assemblages offshore of Broward County have changed little since 1997.

**Florida Keys:** Coral reef resources have been degraded by resource extraction as well as habitat loss and damage since the 15<sup>th</sup> century. These long-term changes to coral reefs include: 1) loss of top predators (e.g. monk seals); 2) loss of spawning aggregations and reductions in the abundance of large groupers and snappers; 3) loss of habitat structure including mangroves, corals and seagrass beds; 4) reductions in conch, lobsters and urchin populations; and 5) loss of ecosystem services provided by the aforementioned flora and fauna, including those provided by the once heavily exploited sponge fishery. Hurricanes during 2004-2005 caused some

damage to the coral reefs, but also reduced sea surface temperatures to below critical bleaching thresholds. The mean number of observed stony coral species and coral cover declined at permanent patch-, deep-, and shallow-reef sites throughout the Florida Keys from 1996 to 2006. The coral cover decline is partly due to the loss of major framework building corals, specifically the boulder star coral, *Montastraea annularis*, staghorn coral (*Acropora cervicornis*) and elkhorn coral (*Acropora palmata*) which were once dominant in the Florida Keys. Elkhorn coral populations declined by about 50% between 2004 and 2006 at 5 upper Florida Keys reefs, primarily from hurricane and disease impacts. Staghorn and elkhorn corals were in low abundance on Upper Keys reefs in 2006; staghorn coral occurred at low densities (< 1 colony per m<sup>2</sup>) at fewer than 18% (19 of 107) of sites and in less than 45% (5 of 11) of the habitat types surveyed. Elkhorn coral also occurred in low densities (< 2 colonies per m<sup>2</sup>) at fewer than 17% (18 of 107) of sites and in 36% (4 of 11) of the habitat types surveyed. Data from synoptic surveys suggest that very few Acroporid corals were affected by white band disease, white pox, or tissue necrosis. However, long-term monitoring of *A. palmata* colonies indicates that disease events are highly episodic and significant impacts can occur over short time periods, as evidenced by outbreaks in 2003 and 2005.

**Flower Garden Banks National Marine Sanctuary:** These reefs continued to be in good condition between 2002 and 2006 with consistently high coral cover, ranging from 49.6% to 64.1%, specifically: the *Montastraea annularis* complex covered 26.8 to 40.1%; and *Diploria strigosa* (3.2% to 13.4%). Other coral species include *Porites astreoides* (3.4-8.2%) and *Montastraea cavernosa* (2.3%-7.7%), and 10 other species made up the remaining coral cover. Hurricanes Katrina and Rita passed by the Flower Garden Banks in 2005, but there were few changes in community structure in quadrat images and perimeter video assessments in November 2005.

**U.S. Virgin Islands:** Three long term monitoring programs provide data on USVI coral reefs: NPS/USGS Coral Disease and Benthic Cover Monitoring, Territorial Coral Reef Monitoring Program (TCRMP) and NOAA Biogeography Branch's Caribbean Coral Reef Ecosystem Monitoring Project. Mean live coral cover in northeastern St. Croix and around St. John was 5.6% ( $\pm 0.5$ ), with 9 coral genera in St. Croix and 14 genera in St. John having cover greater than 0.01%. The three most abundant corals, *Montastraea*, *Porites*, and *Diploria* species, had mean cover of 1% ( $\pm 0.09$ ) in St. Croix and 2.4% ( $\pm 0.34$ ) in St. John. Instead, coral reef and hard bottom areas were dominated by turf and macroalgae (48.1% in St. Croix; 43.8% in St. John). However, no significant trend in the ratio between coral to algal cover was detected over 7 years of monitoring. More than 90% of coral cover at monitored sites bleached during the 2005 bleaching event on St. John with significant losses noted from the event as well as post-bleaching disease outbreaks, particularly a white plague-like condition. Within 12 months, coral cover loss at 7 sites ranged from 34.1% to 61.8% with 6,061 disease lesions noted on 23 coral species between September 2005 and July 2006. NOAA data from northeastern St. Croix revealed that approximately 51% of live coral cover was bleached in October 2005, affecting 25 of 30 observed coral species. On St. Thomas and St. Croix, TCRMP data showed that the important framework-building corals (*Montastraea annularis* complex) were hardest hit by bleaching, with some sites losing more than 70% of *Montastraea* cover.

**Puerto Rico:** Coral cover has been variable spatially, temporally and between studies over the years, but all studies report a general decline from bleaching and disease, as well as sediment and nutrient inputs. Up to 97% of corals bleached at monitoring sites with about 50% coral

mortality during the 2005 bleaching event; a massive white plague-like outbreak followed that resulted in 20 - 60% decline in coral cover on the east coast within 6 months. In addition, coral cover in southwest Puerto Rico is inversely correlated with increased turbidity from sediment and nutrient inputs.

**Navassa:** Between 2002 and 2006, coral cover at Navassa declined at deeper sites (22-32 m) by as much as 28.8% at southwest shelf sites, with similar declines in shallow areas (7-22 m) at Northwest Point. In contrast, mean coral cover at Lulu Bay has remained fairly steady at 10-25% over the same period. The major coral species are the *Montastraea annularis* complex, *Siderastrea siderea*, *Porites astreoides* and *P. porites*; however, macroalgae (especially *Lobophora variegata* with maximum cover of 34%, and *Halimeda* and *Dictyota* species as secondary components) is the dominant cover type in many reef habitats. It is not uncommon for macroalgae to cover 36-40%, or even 70% in some areas. Specific monitoring of *Acropora palmata* and *A. cervicornis* was initiated on Navassa since listing under the 2006 Endangered Species Act. Most *A. palmata* colonies in 2006 appeared healthy with only occasional recent mortality observed among 1,800 colonies along 6.8 km of the coast. While only 12 colonies of *A. palmata* were reported in 1998 in Lulu Bay, the population has increased to more than 100 colonies; in contrast, *A. cervicornis* remains extremely rare with only 5 small colonies observed in 2006.

#### STATUS OF CORAL REEF FISHES AND INVERTEBRATES

**Southeast Florida:** In general, the species composition resembles other Caribbean and tropical Atlantic sites, but with an increasing abundance of temperate species (e.g. pigfish, *Orthopristis chrysoptera*) on reefs in the northern section. There are differences in fish assemblages among the parallel reef tracts, with fish abundance and species richness increasing from inshore to offshore reefs. Grunts (*Haemulidae*) are abundant on all reef tracts but predominate on inshore reefs (<12 m depth) and in some estuaries in Palm Beach County. Juvenile fish alone can comprise 60-90% of the total fish assemblage on inshore reefs, whereas on deeper reefs, wrasses (*Labridae*), surgeonfish and doctorfish (*Acanthuridae*) and damselfish (*Pomacentridae*) become more abundant. Large groupers (*Serranidae*) and snappers (*Lutjanidae*) are relatively rare, probably because of high fishing pressure throughout Florida. For example, only 2 of 242 grouper and 219 of the 718 snapper seen during a 4-year survey were of minimum legal size in Broward County, and no goliath or black grouper were recorded. Goliath (*Epinephelus itajara*) and Nassau (*E. striatus*) grouper and queen conch (*Strombus gigas*) fisheries were closed in the 1990s. There are some signs of recovery for goliath grouper.

**Florida Keys:** Several exploited and unexploited reef fish populations in the Tortugas region have shown significant increases in abundance since the FKNMS Tortugas Ecological Reserve (TER) was designated in 2001. Black grouper, red grouper, and mutton snapper were significantly more abundant in the TER in 2004 than in 2000. No significant declines were detected for any exploited species in the TER, while non-exploited species showed both increases and declines. The abundance of exploited species in areas of the Tortugas Bank open to fishing either declined or did not change. In a Florida Keys-wide study, the Florida Fish and Wildlife Conservation Commission observed very little change in the mean length of several target species including *Ocyurus chrysurus*, *Lutjanus griseus*, *L. maximus*, *Epinephelus morio* and *Mycteroperca bonaci* between 1999 and 2006. Most fish observed (89%) were in the smallest size class (>5 to 20-25 cm), and few groupers and snappers observed were in the larger size classes.

The average size of lobsters has increased significantly to larger than the legal size within in the fully protected marine zones of the FKNMS since 1997, whereas the average size of lobster continues to be smaller than the legal size in exploited areas. In addition, legal-sized lobsters in fully protected marine zones were as large as or larger than those in fished areas. Lobster abundance declined in both protected and exploited areas during the open season, but less so in the reserves. The mean size of legal lobsters and the frequency of occurrence of very large lobsters increased steadily within the FKNMS Western Sambo Ecological Reserve since it was established in 1997. Adult queen conch populations in the Florida Keys have begun to recover since the fishery was closed in 1986, with conch density increasing from about 250 conch/ha in 1992 to about 700 conch/ha in 2003; it declined to about 500 conch/ha in 2005.

**Flower Garden Banks National Marine Sanctuary:** A total of 85 fish species were recorded in visual surveys in 2004 and 2005. The highest mean richness per diver survey was at East Bank in 2004 (mean richness = 22 species/survey). Mean fish abundance ranged from a high at the East Bank in 2004 of 251.4 per 100 m<sup>2</sup> to a low at the West Bank of 39.3 per 100 m<sup>2</sup>. In 2005, the mean densities were 96.6 at EFGB and 80.0 at WFGB. Families with the most species were the Pomacentridae, Labridae, Serranidae and Scaridae, with 12 species of Pomacentridae recorded in 2005 at the East Bank. The greatest number grouper species (*Serranidae*) was 9 in 2005 at the West Bank; while 5 scarid species and 7 labrid species were regularly recorded. Long spined sea urchin (*Diadema antillarum*), spiny lobster (*Panulirus argus*) and spotted lobster (*P. guttatus*) populations were assessed in 2004 to establish a baseline. *D. antillarum* populations varied between 0.005 individuals/m<sup>2</sup> and 0.11 individuals/m<sup>2</sup> (44 individuals); but only two *P. argus* were seen in the 2004 surveys.

**U.S. Virgin Islands:** Five years of monitoring fish populations in northeastern St. Croix (1275 locations) and St. John (849 locations) have shown that the biomass of herbivores on St. Croix was higher than piscivores for all survey periods (except August 2001). Similarly in St. John, biomass of herbivores was higher than piscivores for all years except 2003. Fewer than 3% of snappers and groupers observed on transects between 2001 and 2006 were above legal length, and only three individual juvenile Nassau grouper were observed between 2001 and 2006 in St. Croix and nine in St. John. The largest snappers and groupers observed in St. Croix were 30-40% smaller than the maximum recorded size. Large-bodied grouper have decreased in abundance, while small-bodied grouper increased between 1979 and 2006. Similar results were obtained around St. Croix between 2002 and 2005 with herbivore biomass representing approximately 30% of the entire population, and piscivores comprising the least in biomass (10-14%) and abundance (2.7-3.1% of all fish observed). Commercially important snappers and groupers were uncommon in St. Croix. Surveys around St. Thomas between 2003 and 2006 showed no major changes in fish populations. Large-bodied serranids (red hind, *E. guttatus*; Nassau grouper, *E. striatus*; yellowfin grouper, *Mycteroperca venenosa*; yellowmouth grouper, *M. interstitialis*; and tiger grouper, *M. tigris*) were observed at offshore sites, while snappers (*Lutjanus apodus*, *L. cyanopterus* and *Ocyurus chrysurus*) were observed at nearshore and offshore sites, but were more abundant offshore. The St. Croix coral reefs support regionally important populations of queen conch (*Strombus gigas*), but with relatively few large adults. Between 2004 and 2006, significantly more legal-sized (CL  $\geq$ 89 mm) spiny lobster was documented inside Buck Island Reef National Monument in northeastern St. Croix than in the adjacent, surrounding fished areas.

**Puerto Rico:** Shallow water reef fish abundance has generally declined; for example Nassau and goliath groupers (*E. striatus* and *E. itajara*) and queen conch (*Strombus gigas*) are being over-fished, as well as snapper and parrotfish. Fish spawning aggregations have also declined, especially for the larger, more commercially desirable species. Models developed by the University of Miami showed the majority of species are over-fished, with some substantially over-fished. The only large groupers that remain are known to cause ciguatera poisoning in humans. Although there has been a substantial decrease in fishing effort over the last 20 years, there is still an excess of fishing pressure. There has been a shift in community structure of fished groupers in southwest Puerto Rico from 2001-2006. Initially red hind (*E. guttatus*) were the most prevalent species, then the smaller Coney (*Cephalopholis fulvus*) became more prevalent, and most recently the smallest grouper (Graysby, *Cephalopholis cruentatus*) constituted well over 50% of the fished groupers in 2003, and more than 90% in 2006.

**Navassa:** There was a clear declining trend in reef fish biomass between 2002 and 2006, especially for piscivores, herbivores and planktivores (the dominant trophic groups). Fish sizes (mean fork length >10 cm) also showed a significant decline between 2002 and 2004 for grouper, snapper, triggerfish, parrotfish, jack, surgeonfish and squirrelfish families. On the other hand, *Diadema antillarum* abundance has increased over this 4 year interval. The mean density of urchins increased 400% between 2002 and 2006 to approximately 0.16 m<sup>2</sup>, suggesting that recovery is underway on Navassa. Several aggregations of queen conch were observed in 2004, but there was no clear temporal trend.

#### **ANTHROPOGENIC THREATS TO CORAL REEFS**

The top 5 threats to US Caribbean coral reefs include: elevated sea water temperature resulting in coral bleaching; coral diseases; tropical storms and hurricanes; unsustainable coastal development resulting in increased sediment and nutrient runoff; and over-fishing and damage from fishing. However the significance of each threat varies considerably. For example Florida, Puerto Rico and the USVI are heavily populated, unlike the Flower Garden Banks and Navassa.

**Southeast Florida and Florida Keys:** All the coral reef threats above occur along the coastline of Florida. Coastal development and pollution from the large and growing human population in southern Florida probably constitute the most significant stressors to the nearshore marine environment. Impacts associated with coastal construction, dredging for navigation, beach nourishment and infrastructure installation can reduce water quality and increase the damage to coral reefs and hard bottom communities. Wastewater effluents are pumped into the ocean near the reefs via 6 outfalls that discharge 1100 million liters/day of minimally treated wastewater. However, in April 2008, Florida passed legislation requiring effective sewage treatment in southeast Florida including discharging wastewater through ocean outfalls at higher treatment levels by December 2018 and achieving at least 60% recycling of wastewater by 2025. Wastewater management plans have also been developed for Monroe County to minimize pollution from runoff in the Florida Keys, and the state of Florida has mandated that all homes and businesses in Monroe County should be connected to centralized sewage treatment plants by 2010.

Tropical storms have and will continue to threaten coral reefs in Florida. The record-breaking 2005 Atlantic hurricane season directly affected the Florida Keys with 5 major hurricanes

within 5 months. Coral colonies were overturned or damaged, hard bottom areas were stripped of their gorgonians and sponges, and the abundance of juvenile reef fishes such as black grouper was reduced. Those hurricanes also re-suspended significant amounts of sediment and brought cold, upwelled water onto southeast Florida's reefs, dropping water temperatures by 5-10°C.

Although climate change and sea level rise are concerns in Florida, there has been no mass bleaching off southeast Florida since the last GCRMN report in 2004. The mean percentage of bleached (fully bleached, partially bleached and pale) colonies has been less than 4.5% (long-term mean <3%) off Broward County since 2000. Although there was moderate coral bleaching in the Florida Keys in 2005, the passage of several hurricanes mixed surface waters and lowered sea surface temperatures enough that Florida was buffered from the mass coral bleaching event that affected much of the Caribbean.

The occurrence of coral disease at monitoring sites in the Florida Keys has fluctuated annually since 1997, but generally has decreased since 2002. However, the reported decline in occurrence at stations could be related to the decline in coral abundance overall. Similarly the incidence of coral disease is low in southeast Florida, generally less than one diseased colony per site, or usually less than 0.5% of the corals in the community. Vessel groundings in Florida continue to occur regularly, but the numbers reported in the FKNMS have decreased annually from 721 in 2002 to 301 in 2006.

Fish stocks in Florida have been chronically over-fished since the 1970s with the fisheries showing classic 'serial over-fishing' with 23 of 35 reef fish species of groupers, snappers, hogfish, and grunts being over-fished according to federal (NMFS) standards. The average size of adult black grouper in the upper Keys was 40% of the 1940 size, and spawning stocks are now less than 5% of the historical maximum.

**U.S. Virgin Islands and Puerto Rico:** Scientists and resource managers perceive that the top 5 threats above are increasing, while biological resources are decreasing. However, the most dramatic recent losses were due to major coral bleaching and subsequent increased disease incidence in 2005 when sea water temperatures were the highest for the last 14 years. Bleaching conditions persisted for 12 to 15 weeks and were associated with a massive increase in coral disease lesions in the following months. In the USVI, there was a 2530% increase in disease lesions and a 770% increase in denuded skeleton caused by disease, compared to pre-bleaching levels. Bleaching and disease also occurred in deeper coral reefs. The coral bleaching in 2005 and post-bleaching mortality in 2006 also had dramatic consequences for Puerto Rican reefs, resulting in coral mortality of up to 90% at some monitoring sites. The principal reef building species, *Montastraea annularis* complex was seriously affected.

The most common diseases affecting Puerto Rican corals were white plague-II, yellow band, white band, black band, aspergillosis and coralline white band; but the distribution and prevalence was highly variable. Frequent epizootic events result in significant losses of coral cover on most reefs around the island, particularly during the summer; but bleaching and disease disappear when temperatures drop in winter.

Reporting on reef fisheries status remains a major challenge for resource managers, largely due to inadequate data on commercial and recreational fisheries. Managers report that

herbivorous fish catches around St. Croix have increased during the past decade, making parrotfish commercially important. The effects of tourist activities on the coral reefs in USVI and Puerto Rico are not well known. In Puerto Rico, commercial and recreational fisheries land more than 179 edible fish species, as well as many aquarium species. For both jurisdictions, the removal of juvenile fish, queen conch, lobster and herbivorous fish that help maintain healthy coral reefs is of particular concern.

Hurricanes have caused massive damage to coral reefs and associated communities throughout the Caribbean and are a major force structuring reef communities as evidenced by the large-scale destruction of elkhorn coral (*Acropora palmata*) in Puerto Rico. However, no major storms have affected USVI or Puerto Rican coral reefs since Hurricane Georges in 1998.

**Flower Garden Banks National Marine Sanctuary and Navassa:** No people live on these reefs, thus the major threats are hurricanes, or those related to climate change and fishing. Although the Flower Garden Banks are subject to threats related to oil and gas production, including the possibility of accidental spills, contamination from drilling and production effluents and discharges, and pipeline and platform construction and removal, no significant detrimental impacts have been observed on the coral reefs of the FGBNMS from these activities to date.

Since 2000, 5 hurricanes have passed near the FGB including Katrina in August 2005 and Rita in September 2005. Hurricane Rita caused significant damage to the reef including dislodging large (3-4 m diameter) coral heads, and gouging and blasting corals with rubble and sand. Many large barrel sponges were either removed or scoured, and there was catastrophic breakage and toppling of the expansive *Madracis mirabilis* field on the east side of the EFGB. Warmer temperature water sat over the reef cap for 50 days until 23 September 2005, resulting in significant bleaching, with as much as 46% of coral colonies exhibiting some bleaching. In March 2006, 4-5% of coral colonies still showed some bleaching. Severe coral bleaching was also observed on Navassa in November 2006, when little bleaching was observed elsewhere in the Caribbean. The prevalence of bleaching ranged from 15-78% of colonies of all species, with more at deep sites (>20 m) than at shallow (<10 m) sites. The most affected were *Agaricia* and *Montastraea* species, especially *M. faveolata*. Coral diseases at Navassa were rarely seen until 2004, when a severe 'white disease' event was observed affecting 15 coral species. This disease was more prevalent on larger colonies and on *Montastraea* colonies, with active disease evident on 0% to more than 15% of colonies.

Surveys conducted every two years at Navassa indicate that corals have been stressed by episodic events including a white plague-like disease outbreak in 2004 and severe bleaching in 2006. Despite Navassa's status as a National Wildlife Refuge, a lack of effective fisheries management contributes to the threat from excessive fishing pressure, primarily from Haitian artisanal fishermen who have been fishing Navassa's reefs since the 1970s. Fishing pressure may be escalating and the effects are compounded by the use of novel and more destructive gear types, including net fishing, and exploitation of queen conch and Hawksbill turtles.

#### **CURRENT CONSERVATION MANAGEMENT ACTIVITIES**

**Southeast Florida and Florida Keys:** Coral reef conservation and management activities in southeast Florida were limited to those undertaken primarily by local county agencies until 2004. However in 2003, the U.S. Coral Reef Task Force guided the Florida Department of

Environmental Protection (FDEP) and the FWC to develop the Southeast Florida Coral Reef Initiative (SEFCRI) under the goals and objectives of the USCRTF National Action Plan to Conserve Coral Reefs. The Initiative identified key threats to the reefs and resources, and detailed priority actions to reduce those threats. The FDEP Coral Reef Conservation Program (CRCP) was established in Miami to implement the SEFCRI and this has increased awareness of the extensive and unique reef resources and the threats they face along the northern Florida reef tract. This process has led to improved management and coordination among resource agencies, and expanded the network of coral reef stakeholders. The FDEP-CRCP promotes and coordinates research, monitoring, mapping, partnerships, and stakeholder participation for reef conservation and participation in the USCRTF. It has also assumed responsibility for coordinating and leading response to vessel groundings and anchor damage on the reefs off southeast Florida.

In the Florida Keys, assessments, monitoring and research are conducted by many groups, including local, state and federal agencies, universities, private research foundations, environmental organizations and independent researchers, and much of the work is accomplished through partnerships among these groups. Sanctuary staff facilitate and coordinate research by registering researchers through a permitting system, recruiting institutions for priority research activities, overseeing data management, and disseminating findings to the scientific community and the public. For example, since 1994 the FKNMS Water Quality Protection Program has gathered data on water quality, seagrasses, and coral reef and hard-bottom communities, while the Marine Zone Monitoring Program monitors a system of 24 marine reserves located within the FKNMS to determine whether these fully protected zones effectively protect marine biodiversity and enhance human uses related to the sanctuary. Complementing the fully protected marine zones in the FKNMS, the authorization of the General Management Plan of the Dry Tortugas National Park in January 2007 included a no-take Research Natural Area covering 158 km<sup>2</sup> (nearly half) of the park. Lastly, complete, updated and high-resolution benthic habitat and bathymetric maps of the Florida Keys are being developed by NOAA, the FWC, the National Park Service and other collaborators. Color and panchromatic satellite imagery are now available online (<http://oceanservice.noaa.gov/dataexplorer/whatsnew/welcome.html>), and high resolution aerial photography is being used to map Biscayne Bay and characterize unmapped areas of the Tortugas region. In 2007, interferometric acoustic sonar and side scan sonar were used to depict the bathymetry of Hawk Channel within the FKNMS Western Sambos Ecological Reserve, where turbid conditions prevented the use of optical mapping technologies.

**U.S. Virgin Islands and Puerto Rico:** Since the early 1960s, many MPAs have been established in the USVI by Federal and Territorial agencies, including the recently enlarged Virgin Islands Marine National Monuments, Marine National Parks, a Marine Conservation District (MCD), several small marine reserves, Spawning Aggregation Areas (SPAGs) and 18 Areas of Particular Concern. On St. Croix, the East End Marine Park was established in 2003. Existing MPAs vary greatly in size, location and purpose and represent a wide regulatory spectrum, ranging from very little regulation (multi-use areas) to the total exclusion of extractive activities (marine reserves). The few studies inside and outside MPAs in the U.S. Caribbean have highlighted problems related to suboptimal boundary delineations, high human impacts, low resilience to disturbance and limited recovery in marine reserves. The Hind Bank Marine Conservation District south of St. Thomas was established in 1999 and became the first no-take federal

fishery reserve in the USVI, and yielded the first reported recovery of a spawning aggregation. An estimated spawning population of more than 84,000 fish was observed, and nearby grouper and snapper fisheries have improved since the area was closed. Other fish spawning aggregations are being monitored, including Grammanik Bank and Lang Bank. Long-term monitoring of coral disease and abundance, and benthic cover continue as well.

Fisheries management regulations in Puerto Rico have focused on: protecting the integrity of essential fish habitat; banning certain gears in particular locations; imposing size and bag limits; totally prohibiting the harvest of Nassau and goliath groupers; and seasonally closing spawning aggregation sites for groupers and snappers. Managers are improving data collection and obtaining socioeconomic information on the value of the ecosystem to improve decision making. Navigational markers, mooring buoys, and educational signage have been installed to inform boaters and beachgoers about reef conservation, and cleanup efforts are removing unexploded live ordnance in the former Navy training ranges on the island of Vieques. Puerto Rico has designated MPAs in several areas with extensive coral reefs as a first step towards conservation of critical coral reef resources. The Maritime Ranger Unit of 200 rangers enforces coral reef, navigation, fishery regulations and all regulations developed for the MPAs. They are also responsible for ship groundings and coral reef restoration.

**Flower Garden Banks National Marine Sanctuary and Navassa:** Management and regulations are focused on controlling visitor activities in these remote sites. The FGBNMS is protected under the National Marine Sanctuaries Act, with regulations that prohibit: anchoring of any vessel within the Sanctuary; mooring of vessels greater than 30 m on Sanctuary mooring buoys; oil and gas exploration and development within the no activity zone (almost the entire Sanctuary); injuring or taking coral and other marine organisms; using fishing gear other than traditional hook and line; discharging or depositing any substances or materials; altering the seabed; building or abandoning any structures; and using explosives or electrical charges. Management of the FGBNMS is currently being reviewed to address issues identified through a public scoping process, including impacts from visitors, impacts of fishing, boundary expansion needs, pollution impacts, enforcement and education/outreach. Working groups are assisting through workshops and information gathering.

Since the Navassa National Wildlife Refuge was established in 1999, the major issue has been the increasing numbers of foreign fishers and hunters, mainly Haitians, in the refuge. This is challenging because the island is remote with no practical mechanism to efficiently or economically document, manage or address these threats. Although active management is limited, a Haitian NGO, the Foundation for the Protection of Marine Biodiversity, is educating these fishers.

## CONCLUSIONS AND RECOMMENDATIONS

**Southeast Florida and Florida Keys:** Awareness of the socioeconomic value of, and threats to southeast Florida reefs has increased markedly among stakeholders since 2004. New conservation, education and outreach programs, and planning have been developed and implemented, and management is addressing local resource management needs and challenges. However, the pressures of unprecedented development and growth in southeast Florida continue to outpace federal, state, local and citizen environmental protection efforts. Coral reef and hard bottom habitat losses associated with planned public projects continue and the

occurrence of coral bleaching and disease is rising. Pressures from recreational and commercial users are persistent, with serious and often severe consequences for the reef resources. Similarly, management of the FKNMS has been unable to arrest the decline in coral cover and the reduction of the major framework building corals (*Acropora palmata*, and *Montastraea annularis*) in the face of multiple anthropogenic and natural stressors that originate beyond the jurisdiction of the resource managers, such as climate change and algal blooms. Harvested reef fishes and invertebrates remain over-fished throughout Florida; however the average density and size of some stocks have increased within certain no-take areas of the FKNMS since they were established.

Action to reverse this situation is urgently needed and will require a significant increase in effort and support to conserve coral reefs in Florida. Environmental monitoring and research is currently adequate to provide the basis for sound management policy and strategy development; but improved conservation will require adequate and sustained funding for monitoring programs, law enforcement, and improvement of management plans in partnerships with local communities, visitors, and government and non-government agencies. High priority conservation projects in southeast Florida remain unfunded, including water quality monitoring, mapping of the benthic resources of Martin and Miami-Dade Counties, and research on the links between pollution from the land and coral reef degradation. In the end, successful conservation will depend on the willingness of the public, industry, and regulatory agencies to adopt the current recommendations and guidelines, and incorporate conservation in business practices and programs. Success will also depend on effective national and international programs to minimize global climate change.

**U.S. Virgin Islands and Puerto Rico:** Coral reefs continue to be threatened by demographic pressures, hurricanes and global climate change; the latter impacted Caribbean reefs dramatically in 2005 and 2006 with unprecedented coral bleaching and disease. While recognition of the economic, cultural, and scientific value of reefs is increasing, implementation of a community-based vision for their conservation is still needed. Fish populations have shown a declining trend of abundance and size; although the available fishery dependent and independent data have been inadequate to determine the status of some stocks, like queen conch, mutton snapper and yellowfin grouper. Catch composition continues to be dominated by herbivorous fishes, like small parrotfish, rather than large snappers and groupers that dominated fish catches 40 years ago.

Monitoring needs to be directed towards emerging issues, such as understanding bleaching and disease and assessing heat tolerant strains of corals, determining the effects of recreational activity on reefs (fishing, anchoring, boating, snorkeling, petroleum, garbage), and identifying non-point sources of pollution. Exploration, mapping, and characterization of the deeper reefs (30-50 m) are needed around the USVI and Puerto Rico, as these serve as critically important resident, foraging, reproductive and recruitment habitats for commercial fish and endangered turtles and may be an important source of coral recruits for shallower reefs.

Local government can mitigate some threats, such as reducing nutrients and sediments from development-induced erosion, agriculture and poorly maintained septic systems. Other threats from shipping, anchoring and recreational boating can be addressed by installing more navigational aids, and continuing public education and outreach. Greater inter-agency and

inter-island coordination and integration is needed to integrate management and research, improve compliance and enforcement, assess and regulate fisheries and improve coral reef monitoring programs. Management authorities and governments have many of the necessary components for an effective regulatory framework to restore coral reef health, such as establishing and improving MPA management, enforcing existing land use and resource management regulations, and accessing to long-term data from on-going monitoring programs.

**Flower Garden Banks National Marine Sanctuary and Navassa:** The Flower Gardens coral reefs continue to thrive, despite being in the middle of one of the largest oil and gas fields in the world. One unresolved concern is large volumes of contaminated water, or 'produced water' that is generated from offshore oil platforms; the effects of produced water on the coral reefs are unknown and need to be addressed as oil and gas activities continue to expand. These reefs are susceptible to environmental perturbations as the major deleterious impacts of 2005 clearly demonstrated with coral disease and bleaching, and major hurricanes. Current predictions are that these impacts will not be less severe in future. Because these reefs can serve as a standard for comparison to other Caribbean coral reefs and may function as a source of recruits for neighboring regions, their conservation is essential.

It is clear that the remote Navassa reefs are not remote from anthropogenic stress, and are undergoing rapid change. Fishing pressures and disturbances, such as coral bleaching and disease, have resulted in a rapid decline in coral cover, including the death of large coral colonies, and reduced reef fish size and abundance. The occurrence of severe coral disease and bleaching in this relatively deep (25-30 m) and remote location supports the hypothesis that coral loss in the Caribbean is a regional phenomenon, and there are no obvious and effective conservation and management measures to reverse this trend. The jurisdictional/management challenges for Navassa, meanwhile, do not abate.

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# 17. STATUS OF CORAL REEFS IN THE NORTHERN CARIBBEAN AND WESTERN ATLANTIC GCRMN NODE IN 2008

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## ABSTRACT

- The Node is a mix of islands. Some with well developed economies like Bermuda, Cayman Islands and Turks and Caicos, where reef conservation is strong or improving; and developing or exceedingly poor economies (like Haiti) where reef monitoring and conservation needs to expand;
- All northern Caribbean coral reefs except Bermuda were affected during the 2005 major coral bleaching and hurricane year in 2005;
- Reefs were severely damaged, e.g. 34% of corals around Jamaica bleached and half of these died; there is evidence of coral resilience on the north coast;
- The Bahamas, Dominican Republic and Jamaica signed the Caribbean Challenge to conserve 20% of their coastal (including coral reef) resources by 2010, along with other Caribbean states; and
- The invasive Indo-Pacific lionfish (*Pterois volitans*) now occurs in several countries including Bermuda, Cuba, Jamaica, and Turks and Caicos and poses a significant risk to native species.

## INTRODUCTION

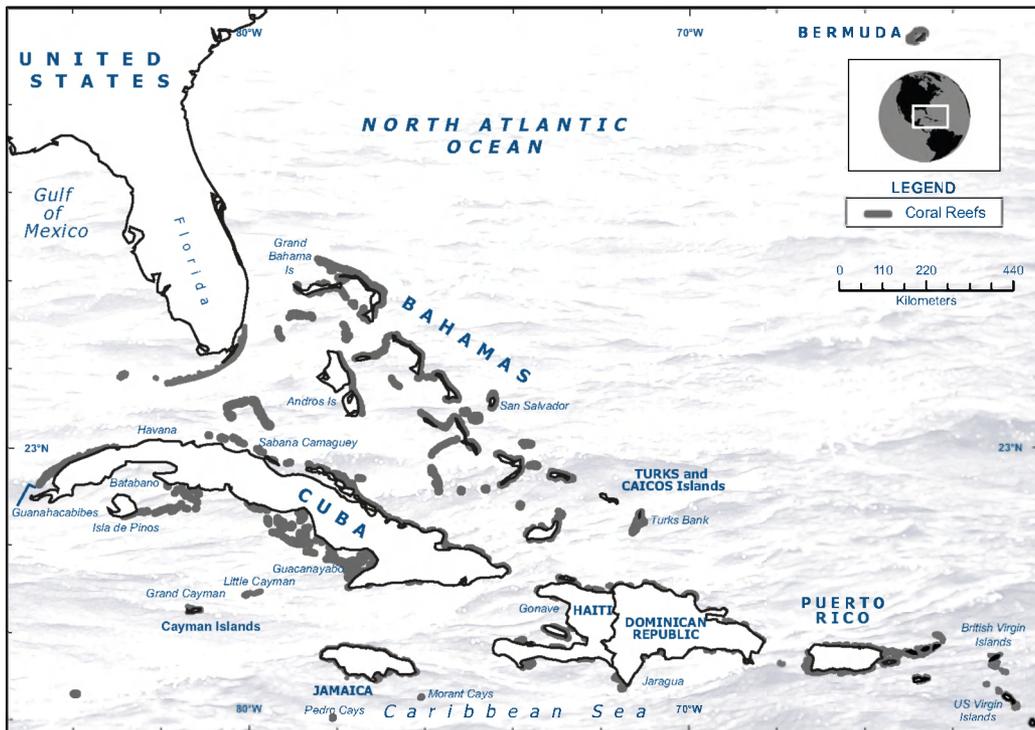
This report updates the status of the coral reefs of the Northern Caribbean and Western Atlantic since 2004 and includes the following: The Bahamas; Bermuda; Cayman Islands; Cuba; Dominican Republic; Haiti; Jamaica; and the Turks and Caicos Islands. The reefs in the northern Caribbean have suffered significant declines since the 1970s from mass mortality due to the grazing sea urchin *Diadema*, new coral diseases, over-fishing and other human stresses, such as nutrient and sediment pollution and habitat destruction. Since 2004 the northern Caribbean has suffered from 12 hurricanes and 8 tropical storms in addition to coral bleaching resulting from elevated sea surface temperatures in 2005. More details and reference material are contained on the attached CD with this printed report.

## Bahamas

The 13 major islands and 700 smaller islands and cays lie on a limestone platform covering 13 880 km<sup>2</sup> area comprised of two large, shallow carbonate banks. The largest is the Great Bahama Bank with Andros Island while the smaller forms a chain extending from the Straits of Florida to the Caicos Islands. The islands are low-lying and comprised mostly of very porous limestone so there is no surface water and therefore corals can grow close to the shore. Coral reefs occur mostly fringing the bank margins, with some small patch reefs on the banks in areas with high tidal circulation and with a few bank barrier reefs.

## Bermuda

The Bermuda islands are a 53 km<sup>2</sup> chain of aeolian limestone islands in the North Atlantic at 32°N, 1050 km off the coast of USA and 1660 km north-east of Florida. The 7 main islands are connected by bridges and have a maximum elevation of 79 m. The climate is sub-tropical and sea surface temperatures range from 16°–30°C. Bermuda's reefs are geographically isolated; there is no land with reef corals nearer to Bermuda than the Bahamas, 1350 km to the southwest. These are the most northerly reefs in the Atlantic and amongst the most northerly in the world. The Bermuda platform of about 990 km<sup>2</sup> (maximum 200 m depth) has an atoll-like reef tract, unique in the Caribbean, and includes patch and terrace reefs covering 550 km<sup>2</sup>. Bermuda has about 22 species of hard corals, but branching *Acropora* species have never been recorded in Bermuda. The shallow outer lagoon, rim and fore-reefs are dominated by massive high relief species such as *Diploria strigosa* and *D. labyrinthiformis*, *Montastraea franksi*, *M. cavernosa* and *Porites astreoides*. Nearshore reefs and deep fore-reef habitats are dominated by branching *Madracis decactis*, *Madracis auretenra* and *Oculina* species.



### ***Cayman Islands***

The Cayman Islands are in the middle of the Caribbean Sea, and consist of 3 small low-lying, limestone islands: Little Cayman; Grand Cayman; and Cayman Brac. The islands are a centre for banking, insurance and legal services as well as tourism, especially the cruise line industry and dive tourism. Fishing pressure is low, supplying only the local markets and the last known grouper spawning site is on Little Cayman. Fishing remains an important cultural tradition in Cayman Brac following activities of the original residents. On Grand Cayman there are numerous large resort hotels, condominiums, private homes and corporate development; whereas the population on the other islands is small. The islands are surrounded by shallow-sloping terraces: the first ends at 8–15 m depth and the lower terrace stops at 15–20 m, before the shelf-edge ‘walls’ that are diver favourites. In many locations there are shallow boulder ramparts formed from the once dominant *Acropora palmata* stands. Most reefs have low to medium relief (1–3 m) spur and groove formations.

### ***Cuba***

This large (110 000 km<sup>2</sup>) high island has 3966 km of coral reefs along 98% of the long shelf edge. More than 50% of these reefs are separated from the mainland by cays or broad shallow lagoons with many patch reefs. This separation has provided protection for the outer reefs from human pressures, except for fishing and some tourist diving. Important reef areas, clockwise from the north-west, include: the Archipelago de los Colorados; the Archipelago de Sabana and the Archipelago de Camaguey on the north coast; and the Golfo de Guacanayabo, the Golfo de Ana Maria, the Archipelago de los Jardines de la Reina, the Archipelago de los Canarreos and the Isla de Juventad on the south coast.

### ***Dominican Republic***

The eastern part (48 500 km<sup>2</sup>) of the large island of Hispaniola is mountainous and large rivers drain extensive watersheds that carry sediments to limit nearby reef growth. Only 27% of the 1400 km shore (average shelf width 8 km) is fringed by mangroves and 12% by coral reefs. Important reef areas on the north (Atlantic) coast include the Montecristi barrier reef in the north-west (the widest shelf), narrow high-energy reefs in the central region and the Bávaro-El Macao-Punta Cana barrier reef system at the eastern end. In the north Samaná Bay receives many rivers and is the largest estuary on the Caribbean island, therefore nearby reefs are poorly developed. The Navidad Shoals and Silver Banks are about 100 km to the north. To the south, on the Caribbean coast, are the well-studied reefs of Parque Nacional del Este and the adjacent Isla Saona. Westward, past Isla Catalina to beyond Santo Domingo, are uplifted carbonate terraces with reefs growing on narrow platforms e.g. Boca Chica and the Parque Nacional Submarino de Caleta. Conditions are not good for reefs in the south-west, except on the shallow sheltered shelf east of Cabo Beata at Parque Nacional Jaragua.

### ***Haiti***

This is the western part (27 600 km<sup>2</sup>) of Hispaniola with coral reefs in the south near Ile a Vache; all around Ile de la Gonave in the central bay of Port-au-Prince; on the Rochelois Bank and at Les Iles Cayemites; off the northern coast of the southern peninsula; and in the north from the border with the Dominican Republic in the east to the Baie de l'Acul just west of Cap Haitien. These reefs experience probably the greatest human pressures of any Caribbean island with serious land degradation resulting in major sediment and nutrient pollution, and severe over-fishing. This was particularly evident with 3 major hurricanes in the summer of 2008.

## ***Jamaica***

Jamaica is the third largest Caribbean island, 230 km long by 80 km wide, with 891 km of coastline and 1240 km<sup>2</sup> of coral reefs. Well developed fringing reefs occur along most of the north and east coasts, while patchy fringing reefs grow on the broader shelf of the south coast. Reefs and corals also grow on the neighbouring banks of the Pedro Cays, 70 km to the south, the Morant Cays, 50 km to the south-west and the Formigas Banks to the north-east. Human pressures are great with over-fishing and pollution from the land affecting nearshore reefs.

## ***Turks and Caicos Islands (TCI)***

The Turks and Caicos consist of 8 islands and approximately 40 low-lying cays on the Turks Bank and Caicos Bank, adjacent to the submerged Mouchoir Bank. More than 300 km of coral reefs surround the islands, and the prevailing easterly trade winds create a clear differentiation on the banks with a windward eastern side and a calmer leeward western side. The banks have narrow discontinuous shelf-edge reefs of variable depth, relief, and hard coral abundance. The shallow fringing reefs along the western Caicos and Turks Banks are well developed near the shore. Shallow patch reefs occur around many islands and cays, and water visibility is considered good everywhere. These islands are a major tourist destination, especially for divers and yachts.

### **STATUS OF CORAL REEFS: 2008**

The most significant event to affect the coral reefs in this node occurred during the major climate-change related events of 2005, which was probably the warmest year on record in the Northern Hemisphere and rivalled 1997–1998. Warm water bleaching and waves from numerous strong hurricanes resulted in major losses of corals in many of the countries, as well as significant damage on the land that resulted in sediment and other pollution flowing onto the reefs. Bleaching was compounded by major outbreaks of coral diseases in 2005 and 2006.

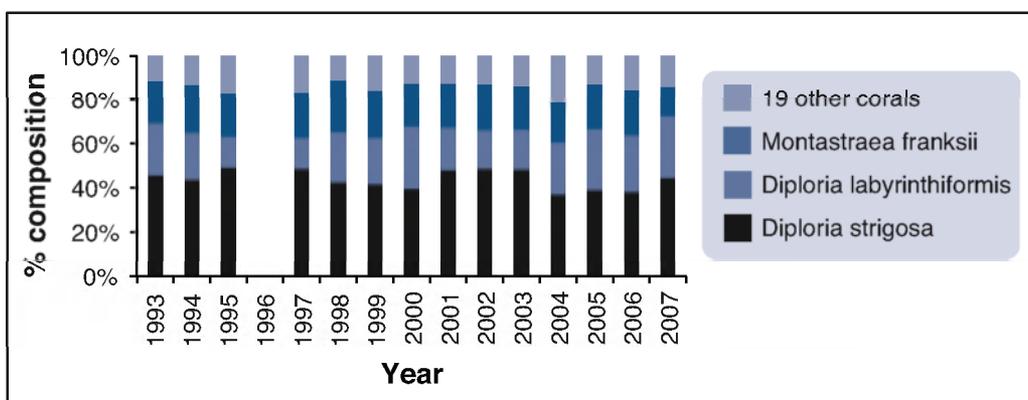
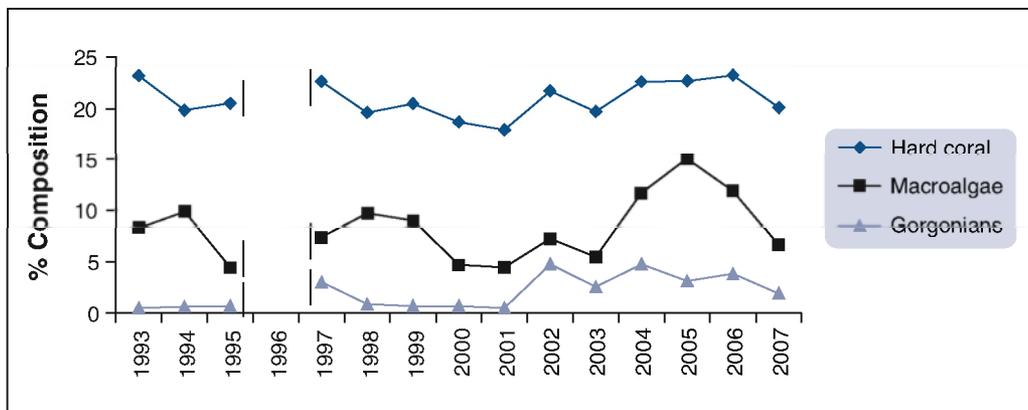
## ***Bahamas***

There are few long term data sets for Bahamian coral reefs, but one example stands out. There was a significant drop in live coral cover from 13% to 3% between 1991 and 2004 at Rainbow Gardens Reef (Iguana Cay, Exumas), as determined by comparing quantitative community descriptors. The number of coral colonies decreased from 295 to 240; thus the coral community was less rich and the resultant reef structure was more homogeneous. Most large *Montastraea annularis*, *Agaricia agaricites*, *Porites porites*, and *Porites astreoides* colonies were absent in 2004. Colonies were also more prone to stresses from algal smothering, excess sediment, and boring organisms; however no coral disease was recorded in 2004. The *M. annularis* skeletons were severely bio-eroded with a bright yellow skeletal band corresponding to an increase in bleaching and coral mortality; which probably resulted in the decline of corals. Thus it appears that a combination of bleaching, bio-erosion, and storm damage reduced the Rainbow Gardens discrete coral patches to rubble.

## ***Bermuda***

These northerly reefs have fared well over the last 25 years, compared with more tropical areas in the wider Caribbean. Although the reefs are adjacent to high human population densities, the economy is strong and considerable income is derived from reef-related tourism; thus there is a relatively strong conservation ethic. Recurrent bleaching events, hurricanes and

coral disease have had little effect on coral cover, which can approach 80–90% on the deeper main terrace reef. Coral cover at one site on the outer rim has not changed in 15 years (i.e. 20.5% in 1992 and 20.1% in 2007). The graphs below show that coral cover up to 2007 has virtually not changed since the 22.5% reported in surveys 25 years ago by Richard Dodge in 1982. Overall there appears to have been little appreciable change in coral cover on Bermuda's outer rim reef in the last quarter century.



***These graphs show bottom cover at Hog Breaker reef (14 m depth) on the Bermuda outer rim since 1993, data collected during the Caribbean Coastal Marine Productivity Programme (CARICOMP). The coral cover line graph includes the hydrocoral Millepora alcicornis; and the bar graph shows that the coral composition is dominated by 3 coral species plus another 19 species (other corals).***

The most common diseases of Bermudan corals are yellow blotch syndrome (YBS), on *Montastraea franksii* and *Diploria* species, and black band disease (BBD) and white plague on *Diploria* and *Montastraea* species and *Porites astreoides*. YBS has higher prevalence at deeper sites (greater than 5 m) and BBD at shallower sites (less than 5 m). The overall prevalence of disease was just over 3% in October 2005 (about 2.5% for YBS and about 1% for BBD) and this was lower than measurements from 1999 to 2001. However, octocoral diseases in 2005 were about 4 times more prevalent in Bermuda than diseases of hard corals. Bermuda has not experienced the long periods of high water temperatures associated with coral bleaching.

### ***Cayman Islands***

There were significant losses of live coral cover on shallow reefs surrounding Little Cayman between 1999 and 2004; but the trend in 2008 appears to have slowed indicating continued coral recruitment and decreased mortality. Average coral cover was 16% in 2004 and 17% in 2008, with no changes in the cover of fleshy macro-algae. AGRRA surveys reported no significant changes in recruitment from 1999 to 2007. For example, in 2005 marked juvenile corals showed that the total density of juveniles and the relative proportions of juvenile coral species did not change following the reduction of coral cover measured to 2004. Juvenile coral community structure was significantly different between and within reefs. In general, densities of brooding *Agaricia* and *Porites* species were higher than the spawning *Montastraea* and *Siderastrea* species but growth and survival of juvenile corals did not differ between species. Coral mortality varied from 23% to 27% and was largely attributed to white plague disease. The abundance of large reef builders (*Montastraea*) decreased while *Agaricia* and *Porites* increased.

Coral bleaching occurred in the Cayman Islands in the late 1980s, 1995, 1998, 2003, and 2005: the most severe bleaching was in 2005 but there was little mortality. Major hurricanes that have hit the Cayman Islands include Allen in 1980, Gilbert in 1988, Mitch in 1998, Ivan in 2004, and Dennis in 2005. Hurricane Ivan passed south of Little Cayman and Cayman Brac, but made direct landfall on Grand Cayman on 12 September 2004. Large masses of sand piled up on back-reef corals and in lagoons on the south side of Little Cayman and Grand Cayman. Corals above 15 m were broken or totally displaced along both sides of the islands, but damage was patchy and recovery is occurring. Boulder ramparts on many beaches of all three islands and reef-crest zones provide historic evidence of the continuous impact by major storms.

### ***Cuba***

AGRRA assessments in 2007 reported live coral cover from 9–50% for reef crests in the south and east of the Golfo de Batabanó and from 6–21% for the fore-reef zones in areas affected by 6 hurricanes from 2001 to 2005. There have also been shifts in coral species dominance at most sites. Live coral cover along the Archipiélago Jardines de la Reina, south-east Cuba was 7–19% (7–12% on reef crests, and 16–19% on fore-reefs). Previous AGRRA assessments in 2001 reported coral cover at 3–38% (mean 16%: 3–38% on reef crests, 10–23% on fore-reefs). The loss of coral cover at reef crests was presumably due to the category 4 Hurricane Dennis in 2005. Coral cover in 2002 was 20–39% at 12 sites between 3 m and 15 m depth, in eastern Bahía de Cochinos (south central Cuba). Similarly coral cover was 14–28% at 4 sites at 6 m and 40 m depth. In 2003 at Guajimico coral reef (east of Cienfuegos Bay, south central Cuba) coral cover was 20–25% at 14 sites (5–20 m deep). For 13 sites in north-western Cuba (Cayo Levisa; north Pinar del Río province) coral cover was 30–40% at the reef crest and 10–20% at the fore-reef in 2002 and 2003. Reef Check data collected from 13 stations in 2004 showed an average of 22.8% while for stations monitored in 2005 the average was 20.7%.

**Dominican Republic:** Areas favourable for reef growth are opposite dry areas and on the platforms of Montecristi, Macao–Punta Cana, Parque Nacional del Este, Parque Nacional Jaragua and the Silver Banks (170 km to the northwest of the island). There are 64 coral species identified in the Dominican Republic. Coral cover varies from 9–40% because of natural causes and human impacts. In 2004, mean coral cover was 11.4% at 6 sites (range 5.0–20.8%). Reef Check assessments in 2005 at 11 sites reported coral cover as 14.9% (range 1.9–30.6%). In 2006 at 8 sites the mean coral cover had increased to 21.9% (range 8.1–34.4%). Thus coral

cover has almost doubled from 2004 to 2007. This is good news after the damaging losses in the 1980s and 1990s and the big bleaching year of 2005. No data are available after the damaging hurricane season in 2008.

### ***Haiti***

There have been no comprehensive coral reef surveys since the 2003 Reef Check surveys of 5 sites north-west of Port-au-Prince, when the reefs appeared to be fairly healthy. There is no government involvement in coral reef monitoring or conservation in Haiti and only one small NGO monitors the reefs and provides education. But there is clear evidence of continuing degradation to reefs from eutrophication, sedimentation, coral harvesting, pollution, and over-fishing.

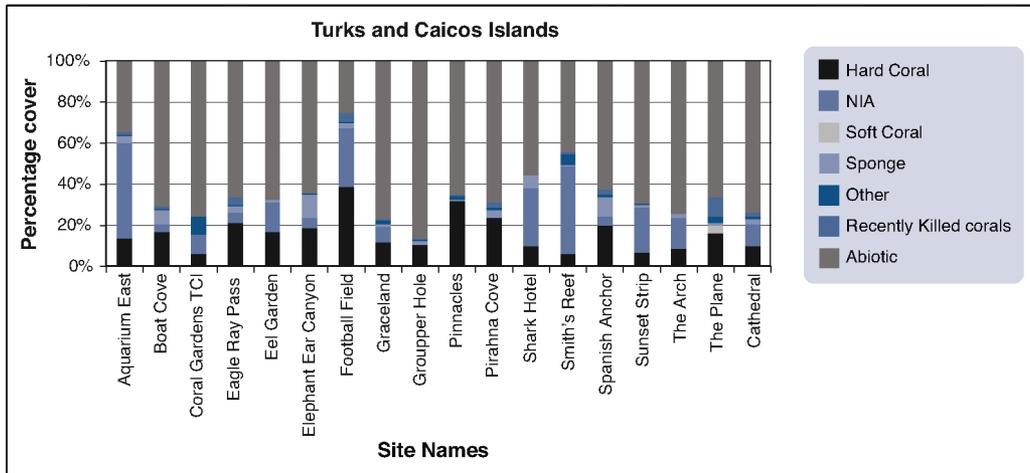
### ***Jamaica***

There has been a mix of reef decline and recovery between 2001 and 2007 which included periods of elevated sea surface temperatures and several major hurricanes. Average coral cover was 14.8% (range 2.2–37.5%): generally, very shallow reefs (3 m or less) have lower coral cover. Coral cover less than 10% was at 18 of 53 sites, showing continued severe stress, with Jamaican reefs continuing to be more degraded than the rest of the Caribbean. The good news is that Jamaican reefs have rebounded from the 5% average coral cover in the early 1990s, with mean estimates in 2008 being 15%, a threefold improvement. Moreover, some reefs have relatively high and stable coral cover exceeding the Caribbean average (12 sites above the regional average of 20%). On fringing reefs around Discovery Bay on the north coast coral colony size reduced for many species in 2006 after the mass bleaching of 2005, with subsequent increases in 2007 and 2008. Coral bleaching in 2005 was severe but with relatively little mortality unlike the nearby US Virgin Islands. At Dairy Bull Reef total coral cover and *Acropora* species (13% and 2% respectively in 2006) increased in both 2007 (20% and 10%) and 2008 (31% and 22%). These studies indicate strong resilience on the fringing reefs around Discovery Bay in Jamaica. The trend of algal dominated reefs is, however, still visible on reefs around the island with coverage by algae (indicating increased nutrients) ranging between 0–62.9% with an island-wide average of 24.2%.

### ***Turks and Caicos Islands***

About 50–75% of coral colonies suffered partial to total bleaching in 2005 on their reefs resulting in losses of live coral around most islands. Rapid assessments in 2006 and 2007 of 18 sites around the 3 major islands reported that live coral cover averaged 10%–20% with an approximate maximum of 40%. Coral cover at Providenciales ranged from 6–38% which was higher than 2004 estimates; algal cover ranged from 0–46%. There was lower coral cover on shallow inshore sites than on the deeper offshore reefs, possibly indicating a range of human stressors. Average coral cover in West Caicos was 17% with low algal cover while in South Caicos there was 9–16% coral cover and 15% macro-algal cover.

The high abundance of algae and the zonation patterns of species in many shallow locations indicate probable land-based sources of nutrients. However, high levels of algae were also seen at many places with no land influences. The horizontal and vertical gradients of algae at these locations suggest that the nutrients come from upwelling of cold, deep, nutrient-rich water from offshore.



**Coral cover at 8 sites around Providenciales in 2007 show comparable cover of hard and soft corals and variable but relatively high cover of turf or macro-algae.**

## STATUS OF MANGROVES, SEAGRASSES AND FISHERIES: 2008

### Bermuda

Bermuda has a highly regulated fishery with relatively large seasonally protected areas, protected species, limited entry, gear restrictions and bag limits. Reef fish populations showed signs of over-fishing in the 1980s when the preferred target species were rare in fish traps. This decline and the ultimate ban on fish traps in 1990 resulted in a shift towards pelagic species, particularly wahoo (*Acanthocybium solandri*) and yellowfin tuna (*Thunnus albacares*). Now pelagic species account for about 50% of commercial finfish landings. Populations of critical herbivores (parrotfish) and the large black grouper (*Mycteroperca bonaci*) have increased. Landings of other high target grouper species, *Epinephelus guttatus* (red hind), and *Cephalopholis fulva* (coney) have been fairly stable but there has been little recovery of other large grouper populations. This is probably related to the reduced reproductive output of smaller fish and destruction of seagrass and mangrove nursery habitats. Harvests of target species of snapper (Lutjanidae), jacks (Carangidae) and spiny lobster (*Panulirus argus*) are variable with no trends over the last decade. Threats to the reef fisheries include a large, virtually unregulated recreational fishery; non-compliance with regulations; insufficient enforcement personnel and inadequate penalties. There are very few documented marine invasive species in Bermuda, however, the Indo-Pacific lionfish (*Pterois volitans*) has established populations since 2002 throughout Bermuda from the shallows to 80 m depth and threatens populations of small and juvenile fishes.

There have been considerable losses of seagrass habitat, possibly as high as 25% of the total; now there are few 'undisturbed' areas. Most losses are on the rim reef and lagoonal locations far removed from obvious human stressors. The reasons for these losses are unknown. Mangrove forests in Bermuda were never extensive but were probably more widespread than today: pre-settlement mangroves probably covered 0.25 km<sup>2</sup> and now the area is probably 0.18 km<sup>2</sup>. One of the largest mangrove forests was severely damaged by Hurricane Fabian in 2003.

### ***Cayman Islands***

Herbivorous fish populations have not changed overall with similar size structures for each species, except parrotfish, since 1999. Parrotfish density has declined significantly, especially on the leeward (north) side of the island. However, parrotfish, groupers and snappers showed significant increases in size of individual fish between 1999 and 2007, which may reflect differential sampling of rare species. Parrotfish showed the greatest increase in size. Over-fishing of conch and lobster, and lack of protection of turtle nesting sites from coastal development are major issues. Residents (of at least 5 years) can obtain speargun and seine net licenses and permits to capture turtles if they can prove these activities are a cultural necessity. Now there are 500 speargun licenses in the Cayman Islands. The growth of the hotel industry with more workers from other Caribbean countries and the Philippines has increased exploitation of marine resources.

Studies of mangroves and seagrass beds began with the completion of the Little Cayman Research Centre in 2006. Mangroves are abundant around the major sound on the south side of Little Cayman and along the north and south coasts inland fringing brackish water ponds. Mangroves and seagrass beds are under intense threat, especially on the western coast of Grand Cayman. Results from the little Cayman mangrove and sea grass studies (2006–2007) indicate no change in productivity and biomass.

### ***Cuba***

Recently, the Ministry of Fishery Industry banned the use of set nets (Resolution 058/2004, Ban of set net deployment) and implemented a policy to reduce bottom trawling by 25% per year in the finfish fisheries. This ban was aimed at stopping seagrass bed degradation and to allow fish stock recovery: affected fishermen are given generous subsidies, alternative livelihoods or opportunities to participate in technical educational.

Mangrove forests cover is 4.8% (5569 km<sup>2</sup>) of the Cuban Archipelago, placing it ninth in the world and third in tropical America. The forests contain *Rhizophora mangle*, *Avicennia germinans*, *Laguncularia racemosa* and *Conocarpus erectus*. The mangrove forest at Golfo de Batabanó is remote from coral reefs and decreasing due to harvesting of the red mangrove and exacerbated by coastline erosion from rising sea levels and storm surges. The main management difficulties include insufficient enforcement caused by limited personnel, vehicles, portable communication facilities, and rehabilitation capacity. This is resulting in local degradation of forests from fires, illegal felling, etc.

### ***Dominican Republic***

The main problems facing reefs are over-fishing of essential species such as conch, lobsters, groupers, snappers and parrotfish. Several non-official institutions, as well as the Secretaria de Medio Ambiente y Recursos Naturales have programs for conservation of marine and coastal habitats, communities and species.

### ***Haiti***

Lobster and conch exports have been suspended under CITES regulations because of over-exploitation and the absence of any form of management. However, illegal coral harvesting continues; mangroves continue to be exploited at an alarming rate for fuel wood, charcoal

production and construction; and seagrass beds continue to be threatened by sedimentation and pollution. A rapid socioeconomic study was made of fisheries along the southwest tip of Haiti by NOAA specifically to understand exploitation in the US National Wildlife Refuge at Navassa Island.

### ***Jamaica***

The un-sustainability of current fishing practices is evident in the depletion of the near-shore fishing stock and a change in the composition of fish communities. The overall mean densities of snappers, grunts and parrotfish were between 0 and 31.5 fish per 100 m<sup>2</sup> averaging 1.4/100 m<sup>2</sup>. High fishing effort, possibly combined with environmental factors, has resulted in significantly reduced fish stocks. Over-fishing remains a problem as the observed net size and pot density appear unsustainable. Low fish and *Diadema* densities have also contributed significantly to the prevalence of algae on the reefs, with *Diadema* densities (average 20.7/100 m<sup>2</sup>) being too low to have any significant effect on algal cover. Despite the lack of herbivores some reefs have shown signs of stable coral cover. In the Portland Bight Protected Area preliminary indications are that the urchin *Echinometra viridis* is now controlling algal growth.

The lionfish *Pterois volitans*, an Indo-Pacific aquarium fish, now occurs in Jamaica and in other Caribbean countries. This invasive and poisonous fish may destabilise reef fish populations and coral health by feeding on grazing fish. The Ministries of Health and the Tourism have been advised of these potentially toxic fish in Jamaican waters.

### ***Turks and Caicos Islands***

Similarly, lionfish are now common at several locations in Turks and Caicos waters. Nearshore seagrass beds and mangroves continue to be in good health, however, there is inadequate monitoring of these systems.

## **CONCLUSIONS AND RECOMMENDATIONS**

The climate change-related threats of increased frequency and incidence of intense hurricanes coupled with rising sea temperatures that result in coral bleaching are now annual dilemmas facing the islands. Coastal ecosystems are stressed more frequently and therefore have less time to recover before the next damaging episode.

### ***Bahamas***

These results clearly demonstrate that their coral reefs are in a near crisis situation. Even shallow, and presumably stable, coral reefs in remote localities have undergone change. However, some patch reefs near Rainbow Gardens appear less degraded suggesting that local, small-scale differences may be important components of reef resilience (Pante, 2007).

### ***Bermuda***

Research and monitoring in Bermuda has increased in the last 4 years with large-scale and long-term programs established to assess corals; algae; fish communities; seagrass cover and seasonality; and water quality (temperature, nutrients, dissolved inorganic carbon, light attenuation). All marine habitats are being mapped into a GIS database to support research and management. Recent management developments include:

- The Protected Species Act (2003) which mandates active intervention to increase protection of all threatened and endemic species and develop recovery plans;
- The Fisheries (Protected Areas) Order which now includes recently discovered grouper spawning aggregations;
- The Fisheries (Antifouling Paints Prohibition) Amendment Regulations (2005) which bans the importation of antifouling paints containing organotins, or herbicides such as diuron or irgarol;
- A Total Economic Valuation model of Bermuda's coral reefs which is being developed to assist in integrating policy and decision-making for marine developments. The model can be used to establish damage compensation fees following ship groundings, and assessing costs and benefits involved in dredging shipping channels.

A Bermuda Government White Paper on The Marine Environment and the Fishing Industry in Bermuda in 2005 contains a commitment to enact conservation measures, which focus on education and public awareness, scientific research, recovery plans for species and habitats, addition of more marine parks and better information management. The White Paper explicitly outlines the position on MPAs, bio-prospecting, scientific research, shipping, impacts of recreational boating, dredging, marinas, moorings, mariculture, aquarium collecting of ornamentals, mining of the seabed, solid waste disposal, sewage, oil/gas spills, land-based sources of pollutions, anti-fouling paints and marine debris/dumping. Bermuda would benefit from additional legislation to protect the marine environment. For example, there are no specific laws regarding ship damage to habitats; and the Bermuda Planning Act does not extend into the marine environment.

The following recommendations focus on coral reef monitoring, conservation management, capacity building, education and outreach activities:

- Increase government funding for long-term research and monitoring;
- Continue implementation of the Protected Species Act and associated recovery plans;
- Formalize the use of Environmental Impact Assessments for major marine developments;
- Incorporate Total Economic Value models into legislation regarding mitigation, remediation, and restitution following environmental impacts;
- Adopt existing, and develop more, habitat specific conservation and management plans;
- Increase funding and staffing for all environmental programs and initiatives;
- Continue to improve existing educational programs; and
- Educate the judiciary and legislators about the importance of the marine environment.

### ***Cayman Islands***

Marine protection laws have been revised to reduce the catch of lobster and conch during the open season. Laws to close spawning aggregations have been established and enforced. Permanent moorings numbers have been reduced to lower diver impacts in Bloody Bay. Monitoring is a standard component of the management in the Cayman Islands and coastal environmental management and coastal planning departments are faced with the challenge of an increased demand for coastal development since 2005. This development may create a risk for much of the productive mangrove habitats.

## **Cuba**

The loss of live coral in southern Cuba was mainly due to unusually frequent and intense hurricanes from 2001 to 2006 and to increases in diseases. In north–central Cuba the main causes seemed to be macro-algal proliferation due to very low abundance of herbivores (parrotfishes and *Diadema*), and to the gradual impact of microbial diseases. Considerable effort is given to coral reef, seagrass and mangrove forest protection despite major economic constraints. Efforts include intensive pollution control strategies, such as obligatory tertiary wastewater treatment in tourist developments, the gradual eradication of unsustainable and harmful fishing practices (set nets and bottom trawling) since 2004, the implementation of new MPAs, and a sustained environmental education campaign. These actions are included within the new third phase of the UNDP/GEF Sabana-Camagüey Project, as well as national and local initiatives. Future challenges include:

- Full implementation of the official ban (MIP-CITMA Joint Resolution No. 1/97) on coral collection;
- Additional improvement of fishery regulations, with full protection of parrotfish;
- Provision of alternative livelihood generators through increasing ecotourism, promoting and implementing sustainable economic practices in tourism, fishery, agriculture/cattle raising sectors; and
- Additional improvements to laws and regulation enforcement.

## **Haiti**

There are no MPAs and, even if they were introduced, it is unlikely that current levels of human damage could be much reduced. The following actions are recommended:

- Establish at least one MPA;
- Establish permanent monitoring sites to collect baseline data;
- Implement marine pollution mitigation measures;
- Promote reforestation and the use of alternative fuel sources;
- Expand public educational activities; and
- Increase public sector responsibility and accountability in resources management.

## **Jamaica**

It is important to implement sustainable monitoring programs which inform on the status of the reefs and act as effective warning systems when reefs are threatened. While the outlook is still bleak for the fishing industry due to the significant reduction in the near-shore fishery, public education campaigns, coupled with continued monitoring and effective management, may yet reverse existing trends and lead to the recovery of the Jamaican reefs.

Climate change damage to coral reefs in Jamaica will ripple throughout the socioeconomy of Jamaica especially through continued decline of fish catches. Recent management responses have included:

- Implementing a stringent permit and licensing system for activities which damage coral reefs;
- Increasing the number of sites being monitored, as well as the frequency of visits;
- Implementing public education campaigns on the importance of coastal ecosystems with special emphasis on the direct correlation between the loss of habitat and general economic losses of the country.

The quandary facing managers remains balancing conservation and economic growth. There is a chronic shortage of human and financial resources to implement effective monitoring and conservation programs. This is hindered by inadequate enforcement, outdated legislation and fines that are ineffective in halting the continued degradation of the island's natural resources

### ***Turks and Caicos Islands***

There are distinct gradients in human pressures with some islands being more developed than others, with a construction boom on some with associated stresses. The Department of Environment and Coastal Resources continues to improve capacity to monitor and track these changes and they have increased the level of public information. Coral reef conservation has focused on removing corals threatened during construction and attempting reef restoration with small scale engineering processes. Efforts have also been made to strengthen the legislation with newly drafted laws.

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## 18. STATUS OF CORAL REEFS IN THE MESOAMERICAN REGION

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ADONI CUBAS, JOSE JUAN DOMINGUEZ-CALDERON AND  
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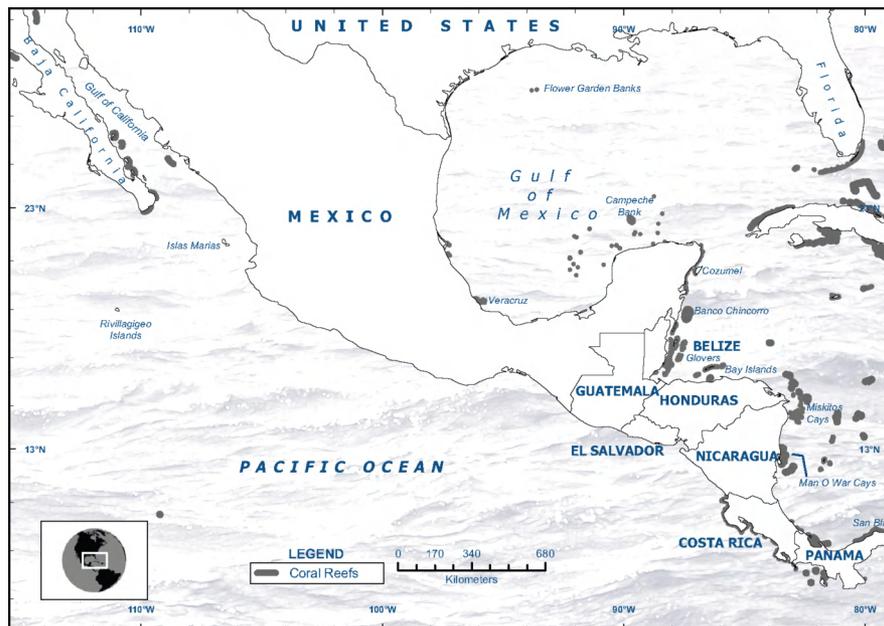
### ABSTRACT

- The Mesoamerican Barrier Reef System (MBRS/MAR) region has received increasing recent attention as a priority for international conservation organizations to provide more research and conservation effort;
- Human and natural threats are continuing, resulting in declining reef condition;
- Live coral cover has declined greatly while chronic human stresses escalate, in parallel with environmental changes and natural events. Coral cover on some reefs has declined by more than 50%;
- A 2006 comprehensive survey of 326 representative reefs revealed regional coral cover averaging 11% (11% Belize, 7.5% Mexico Yucatan, and 14.4% Honduras & Guatemala combined); but some sites have higher cover;
- Mesoamerican Barrier Reef System (MBRS) project found coral cover from 11–26% at 13 strategically selected sites from 2004–2005 (most/all within MPAs); 96 new surveys in 2007 to 2008 on shallow fore-reefs (2–5 m) in 6 Belize regions showed coral cover of 13%; total fish biomass had declined (average 49.8g per m<sup>2</sup>); coral and fish abundances are below the Caribbean average;
- Low coral cover indicates that reefs have not recovered from the 1998 bleaching and Hurricane Mitch;
- It is urgent to develop measures to increase reef resilience and lobby for stronger protection of reefs in good health.

## INTRODUCTION

The main feature of this region is the Mesoamerican Reef (MAR), containing the longest barrier reef in the Western Hemisphere (Belize), 4 offshore atolls and several other diverse reef structures, all extending for 1000 km from northern Yucatan in Mexico, through Belize and coastal Guatemala and out to the Bay Islands in Honduras. These reefs help stabilize and protect the coasts, and serve as feeding and nursery habitats for marine mammals, reptiles, fishes and invertebrates; many of which have great commercial importance. Mesoamerican reefs, however, have been significantly damaged recently due to a combination of human and natural perturbations, with threats ranging from fishing, tourism and coastal development, land use and agriculture to global climate change. A number of 'natural' disturbances have threatened the reefs, especially coral bleaching, hurricanes and disease outbreaks; all of which may be accentuated by global climate change and thus not entirely 'natural.' Such events are not readily controllable at the local management level, while other human threats are potentially under local, national, or regional control. Reef managers in the region, however, are often limited by the resources and 'toolbox' methods available to carry out necessary interventions such as fisheries regulation, protection of coastal habitats, agricultural run-off and sewage pollution reduction, as well as possible restorative activities.

In the 1980s reefs within the MAR experienced the first large-scale impacts, diseases became very evident and widespread throughout the Caribbean, and the first mass coral bleaching from elevated sea temperatures destroyed corals across the Caribbean. *Diadema antillarum* (long-spined sea urchin) and *Acropora* species suffered wide-scale mortality from disease in the early 1980s: 95% of *Diadema* died within the region which allowed algal growth to accelerate quickly on many reefs. The MAR were no exception, however, inadequate quantitative data hampered interpretation of the ecological changes. It was recognised that abundant herbivorous fish populations had probably kept algal growth within ecologically tolerable limits.



The first major ocean warming event in 1983 resulted in some bleaching in the MAR, but the effects were not extensive. According to Carilli and Norris, 2008, the stress to MAR reefs was very minimal when compared to that of 1998. MAR had experienced bleaching episodes in 1995, 1998 and 2005, but 1998 had by far the greatest impact when reefs were damaged extensively by the combination of a mass bleaching event and a category 5 hurricane (Mitch). These synergistic events, combined with chronic 'background' stresses, caused dramatic reductions in live coral cover on reefs with 50% or more coral losses. Coral cores taken from 5 locations along the Mesoamerican Reef have proven that no similar wide-spread mortality events occurred before (more details in *Status of Coral Reefs of the World: 2002, 2004* reports, The 2005 Caribbean Bleaching reported in 2008 and on [www.mbrs.org.bz](http://www.mbrs.org.bz)).

Increasing attention has been given to MAR since these events, especially on science and conservation by local and international agencies. The increased global significance of MAR reefs is evidenced by the establishment of regionally focused projects and initiatives including the Mesoamerican Barrier Reef System (MBRS) Project, a Global Environment Facility/World Bank project (entering the second 5-year phase); the World Wildlife Fund (WWF) Mesoamerican Reef Ecoregional Program; The Nature Conservancy (TNC) Mesoamerican Reef Program; the Wildlife Conservation Society (WCS) marine program in Belize; the International Coral Reef Action Network Mesoamerican Reef Alliance; and the multi-organizational Healthy Reefs for Healthy People Initiative. Globally, the immense value of coral reefs has recently received increased study and economic analyses, with conservation being only one of many values. Research is increasingly aimed at understanding reef status and condition to support conservation efforts. The MBRS Synoptic Monitoring Program (SMP) is an example of new applications to assess coral reefs and associated ecosystems: this is being applied in MPAs to gather reliable data on reef status based on standardized monitoring methods.

Information is targeted at natural resource managers by reporting on the status and trends in marine and coastal resources. Since inception, the Program has established baseline information for 13 MPAs in 2004–2005 based on research in the MAR. Average live coral cover of these prime sites in 2004 was 23% for the 13 targeted MPAs across the region in Mexico (3), Belize (7), Guatemala (1) and Honduras (2). Maximum coral cover was 50% on deep fore-reef sites while 2% was the minimum cover at shallow fore-reef sites. Average fish density at MBRS sites was 35 fish per 100m<sup>2</sup> with ranges from 5 to 111 fish/100m<sup>2</sup>.

A comprehensive study of 326 reefs within the Mesoamerican Reef by WWF and TNC between late 2005 and late 2006 examined different reef habitats, including shallow fore-reef, patch reef, reef pinnacles and back reef/reef flat sites, to offer a snapshot of the ecological health of MAR. The regional average for coral and macro-algae cover was 11% and 18% respectively; total fish biomass was 49.8 g/m<sup>2</sup>, with herbivorous fish averaging 26.2 g/m<sup>2</sup> and commercial fish averaging 11.3 g/m<sup>2</sup>. Thus reefs within the region have not recovered from the synergistic impacts of the 1998 mass coral bleaching and Hurricane Mitch, and this is worrying when the future may bring increases in storms and coral bleaching associated with climate change and increasing sea surface temperatures. It is urgent that all measures be applied to increase the resilience potential of these reefs and that lobbying be enhanced to gain greater protection for reefs in the best health. The recovery rate of coral populations can be greatly diminished by macro-algal blooms, thus it is very promising that the coral to macro-algal cover ratio remains fairly low.

Also promising is that recent average coral mortality (based on 326 sites) was only 1.2%; which indicates that these reefs were not significantly damaged by the 2005 mass bleaching event, the most severe on record in the Caribbean. Very little residual bleaching was observed in the following year which could indicate the innate potential of these reefs to rebound from large-scale natural stresses. However, many storms passed through the region from June to late October 2005 and these helped increase shallow water circulation thereby reducing water temperatures and enabling corals to recover rapidly. It is very important that research be focused on ascertaining the ability of these reefs to 'bounce back' from such climatic related stress, since no conclusive results could be drawn from the 2005 bleaching event. Furthermore, many in the reef science community consider that continuous monitoring over a series of bleaching events is needed before sound conclusions can be made on the resilience of reefs. Until then, the reference point will be the 'potential' ability of reefs to be resilient. Also monitoring should be complemented with proactive actions to reduce chronic background stresses. Reefs are considered unhealthy if they lack the resilience needed for natural processes of recovery and causes of poor health are often attributed to multiple factors including over-harvesting of herbivores, low coral cover, high macro-algal cover, high sedimentation, and eutrophication.

Based on the WWF and TNC 2006 surveys, no statistically significant difference in average coral cover among reef habitat types (fore-reef, patch reef, reef-flat) was found. Fore-reefs had a mean cover of 9.6%, patch of 8.3% and reef flat of 7.8%, which indicates that fore-reef sites are not necessarily healthier than sites near the shore. In order to have effective management and conservation, there is a need to assimilate the relevant scientific information to determine best management practices for reefs and associated systems.

## **HISTORICAL CONTEXT AND STATUS OF REEFS IN 2008**

The major threats in the region are the destruction of natural coastal habitats by increasing coastal and tourism developments, and increased sedimentation from extensive and unsustainable use of watersheds and inland deforestation.

**Mexico:** The Mexican Caribbean coast consists of partially submerged fringing reefs on the northern Yucatan coast and fully developed fringing reefs, with well developed and extensive spur and groove systems, from Xcalak to Belize. The presence of the Xcalak Trench has fostered the development of twin reef crests and fore-reefs in this area. A wide carbonate shelf, influence from coastal upwelling, and scattered patch reefs characterize the northern section. Offshore are three banks/islands: Arrowsmith Bank, along a submerged platform (ranging from 25–400 m in depth), with patch reefs on its southern section; Cozumel Island with reefs on the windward and leeward side; and the Banco Chinchorro Atoll with highly developed reefs on the windward side with well developed spur and groove systems.

Puerto Morelos and nearby reefs suffered significant coral mortality from Hurricane Gilbert (1988) and the mass bleaching in 1995. Unlike Belize reefs, the 1998 mass bleaching and Hurricane Mitch did not cause widespread coral mortality along the Yucatan coast. Patch reefs at Isla Mujeres and Cancun suffered some mechanical damage and fragmentation from Hurricane Ivan in 2004.

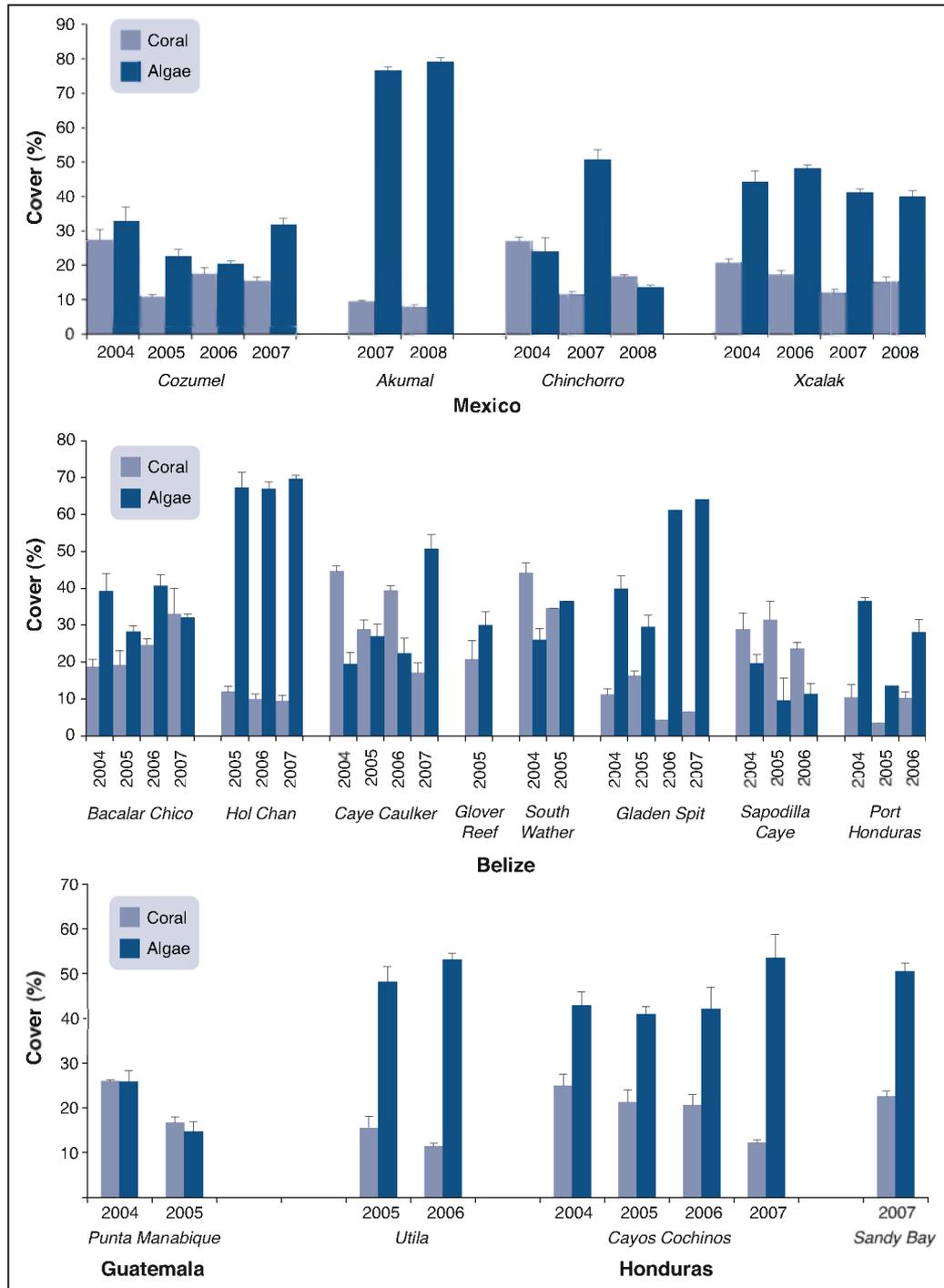
These reefs have suffered from intense fishing activity since the 1960s and increasing pressure from tourism since the mid 1970s. Reef patches at Punta Nizuc and El Garrafon at Isla Mujeres have already been affected by tourism-related activities and the damage appears to be spreading elsewhere to Akumal, Puerto Morelos, Mahahual and Cozumel. Shallow reefs at Cancun, Sian Ka'an and Chinchorro have been affected by boat damage. The reefs just off the northern tip of the Yucatan Peninsula and immediately westward (Punta Mosquito, Boca Nueva, Piedra Corrida) have very little (<2%) coral cover.

The TNC-WWF assessment of 121 reef sites in Mexico from 2005–2006 found average coral cover of 7.5% including shallow fore and patch reefs; reef flats of Sian Ka'an, Cozumel, Isla Contoy, Banco Chinchorro; and some reefs off the Riviera Maya. Total macro-algae cover was 14.9% while fleshy macro-algae cover was 11.5%. Total fish, herbivorous fish and commercial fish biomass was 30.3g/m<sup>2</sup>, 14.5g/m<sup>2</sup> and 8.6g/m<sup>2</sup> respectively.

Data from the MBRS Project in 2004 showed 24% average coral cover in the Xcalak, Banco Chinchorro, and Cozumel Island MPAs. The lowest (18%) was in Xcalak with higher algal cover (41%), which indicates 'alert' status similar to that in Cozumel. However, on Banco Chinchorro conditions are better with less than 25% algal abundance and higher coral cover (26%). The most common reef fish species are from Family Pomacentridae, mainly in Banco Cahinchorro and Xcalak. Cozumel had the second highest fish densities for the region, and Banco Chinchorro has the largest algal grazing (herbivore) population living on the deep fore-reef.

**Belize:** The longest continuous barrier reef system in the western hemisphere extends 260 km along Belize. As well, there are diverse assemblages of lagoonal patch reefs, fringing reefs, faoes and offshore atolls (covering 1400 km<sup>2</sup>). The reefs were once considered to be amongst the most flourishing reefs of the Caribbean, but are now generally on par with the rest of the Caribbean with the reefs damaged by a combination of punctuated disturbance events and chronic stressors, leading to declining coral cover and increases in macro-algae. A few reefs appear to have undergone phase-shifts from domination by living corals to macro-algae. Hurricanes and more recent coral bleaching and disease represent the main widespread disturbances.

Belize's reefs became the focus of serious investigation in the 1960s and 1970s and a series of expeditions followed, driven particularly by the development of the Carrie Bow research station by the Smithsonian Natural History Museum. Prior to 1998 Belize reefs were regarded as being in relatively 'good' condition, however, coral bleaching, disease and major Hurricane Mitch in 1998 degraded the majority of reefs. Coral cover was 25% in 1992 on several barrier reef sites off Ambergris Caye (Tackle Box site) and 20% at Gallows Reef. In 1993 there was 84% coral cover on the shallow Mexico Rocks patch reef off Ambergris Caye; this dropped to 66% in 1995 following the 1995 coral bleaching event. Prior to 1998 most reef losses in Belize were probably from diseases, excess nutrients, sedimentation, loss of *Diadema*, moderate over-fishing, and bleaching. The 1998 bleaching and hurricane disturbances amplified these on-going declines.



*Coral and algal cover on reefs in Mexico, Belize, Guatemala and Honduras monitoring sites between 2004 and 2008 measured as percent cover of the bottom with standard errors.*

While live coral cover is only one measure of ecological status, it is the most commonly used indicator or 'dip-stick' of reef health. Decreased coral cover has occurred in those sites in Belize where long-term data are available. The earliest major declines were on shallow patch reefs in Glover's Reef Atoll from WCS studies which reported 80% coral cover in 1971 then 20% in 1996 and 13% in 1999. The inner fore-reef region at Carrie Bow Caye had 30–35% coral cover in the 1970s and had declined to 12–21% by 1995. The fore-reef at Channel Caye (3–15 m depth), an inner-shelf faroe, declined from 85% live coral in 1986 to 60% in 1996, mainly due to disease and loss of staghorn corals (*A. cervicornis*), with partial replacement by thin leaf lettuce coral (*Agaricia tenuifolia*). Subsequent bleaching in 1998 devastated this reef reducing coral cover to 5% in 1999. Average coral cover in Belize is now slightly less than the Caribbean average in the AGRRA database.

The TNC-WWF 2006 assessment of 140 reef sites in Belize found coral cover of 11% (on average) at diverse sites including barrier, atoll, lagoonal, and faroe reefs, as well as MPAs and non MPA sites. Total macro-algae cover was 16% while fleshy macro-algae cover was recorded at 12%. Total, herbivorous, and commercial fish biomasses were 35.4g/m<sup>2</sup>, 17.6g/m<sup>2</sup> and 8.6g/m<sup>2</sup> respectively.

The MBRS Project focused on 7 MPAs (Bacalar Chico; Hol Chan; Caye Caulker; Glover's Reef; South Water Caye; Gladden Spit; and Sapodilla Caye) where average coral cover was 26% (an 'acceptable' level) and 50% of sites had low algal cover, although 3 MPAs had more than 40% algal cover. Bacalar Chico was considered to be 'alert' status, with 19% coral cover, and Hol Chan and Gladden Spit were in a 'poor' condition with 11%, the lowest coral cover. The lowest populations of coral reef fishes were found in Caye Caulker and Gladden Spit; whereas Bacalar Chico had the most abundant species of herbivores on the deep fore-reef.

Assessment of 96 reef sites along Glover's Reef Atoll, Half Moon Caye, Laughing Bird, Port Honduras, Sapodilla Cayes and South Water Caye during 2007–2008 found average coral cover of 11.8%, 20.0%, 16.6%, 8.8%, 9.9% and 11.8% respectively. Fleshy algae cover was correspondingly 26.3%, 31.4%, 31.4%, 24.8%, 34.1% and 25.3%. Total fish biomass was 49g/m<sup>2</sup>, 34.7g/m<sup>2</sup>, 40.5g/m<sup>2</sup>, 31g/m<sup>2</sup>, 25g/m<sup>2</sup> and 37g/m<sup>2</sup>.

**Guatemala:** There is limited reef development along the Caribbean coast, with the best known being the carbonate banks of Punta Manabique, which are dominated by sediment resistant coral species such as *Siderastrea siderea*, and the isolated coral communities and diminutive patch reefs of the Gulf of Honduras. There has been significant degradation of Guatemalan reefs due to the combined effects of hurricanes, flooding and associated sedimentation, and increases in sea surface temperature. The major threat to the reefs of Punta Manabique is sedimentation from deforestation and soil erosion which bring elevated sediment loads and contaminants onto reefs, causing increased coral mortality and algal proliferation. A study conducted in 2000 recorded live coral cover of less than 9% and non-coralline macroalgal cover of 65%.

Assessment of 5 reef sites in Guatemala in 2006 found an average coral cover of 8.5%. These sites included lagoonal reefs off Kingfish, Bajo del Canal, Montaguilla, Cabo Tres Puntas and Cabo Tres Norte. Total macro-algae cover was 12.5% while fleshy macro-algae cover was 7.5%. Total (31.0g/m<sup>2</sup>), herbivorous (8.3g/m<sup>2</sup>) and commercial (13.1g/m<sup>2</sup>) fish biomasses were much lower than elsewhere in MAR.

Only two sites in the Punta de Manabique MPA were monitored by the MBRS Project. The small reef patches had an average coral cover of 26% with the sediment-resistant species (*Montastraea cavernosa*, *Siderastrea sidereal*, *Agaricia* spp.) being most common. These patches experience high sedimentation and river discharge that impedes coral growth and possibly also reduces algal growth due to poor light penetration: low algal cover of 25% was measured. These patch reefs may also serve as reference sites as the first reefs to be affected by human activities, such as sedimentation, nutrient loading, harmful chemicals, and solid waste.

**Honduras:** While only small coral reef communities occur on the Caribbean coast of Honduras (Puerto Cortes, La Ceiba and Tujillo), there are well developed reefs on the outer Bay Islands (Utila, Morat, Barbareta, Roatàn, and Guanaja) and Cayos Cochinos. Well developed fringing and patch reefs are also found eastward (Misquito Cays and Banks) and further north-east of the mainland (Swan Island). The edge of the Honduran continental shelf is almost vertical and has high coral cover. *The Global Coral Reef Atlas* reports average coral cover of 28% on the fore-reefs of the Bay Islands in the early 1990s. A 2001 WWF survey found 12%, average fore-reef coral cover at Roatan/Barbareta with 8% at Cayos Cochinos, lower than the MAR-wide average of 15%. They also found a slightly higher prevalence of coral disease in Honduras than the MAR-wide average (4.4% versus 3.4%), with recent partial mortality (1.8% versus 1.6%). The Bay Islands reefs were relatively healthy prior to 1998, but bleaching and Hurricane Mitch resulted in 18% coral mortality on shallow reefs and 14% on deep reefs along with an increase in coral diseases. The damage from Hurricane Mitch was due to mechanical damage from waves and terrestrial sediment smothering corals. Hurricane Iris in 2001 also affected Honduran reefs through increased river runoff and sedimentation.

Assessment of 60 reef sites in Honduras by TNC-WWF in 2006 found an average coral cover of 14.8% on various reef types at sites including Barbareta, Trujillo, Cayo Cochinos, Guanaja, Puerto Cortes, Roatan, Tela and Utila. Total macro-algae cover was 25.3% while fleshy macro-algae cover was 16.5%. Total, herbivorous and commercial fish biomasses were 113.0g/m<sup>2</sup>, 72.9g/m<sup>2</sup> and 20.6g/m<sup>2</sup> respectively.

Similar reef structures in the Utila Island and Cayos Cochinos MPAs were monitored by the MBRS Project including island platforms at 5 m depth culminating in a steep slope. Utila Island had a low coral cover (16%), considered as 'alert' status, whereas Cayos Cochinos was in good condition with 24% coral cover and the most abundant herbivore fish species on the deep fore-reef, however, both sites had critical levels of algal cover (> 40%).

### STATUS OF CORAL REEFS IN MPAs: 2008

Coral cover in the MPAs appears to have decreased by 10% in only 4 years, although monitoring is not consistent in all countries with different sample sizes in each MPA. Throughout the region, the most dramatic loss of coral was 7% in 2005, with an average loss of 2% in each of the next 3 years.

All MPAs in Mexico report a decrease in coral cover and an increase of algal cover. These reefs were damaged by hurricanes Emily and Wilma in 2005 and the Beta and Gamma storms, with direct losses of coral cover. Parallel increases in algal cover were variable, for example, in Banco Chinchorro algal cover increased to 50% in 2007 and then dropped to 15% in 2008, possibly as an effect of Hurricane Dean in 2007. The Akumal MPA was added to the monitoring program

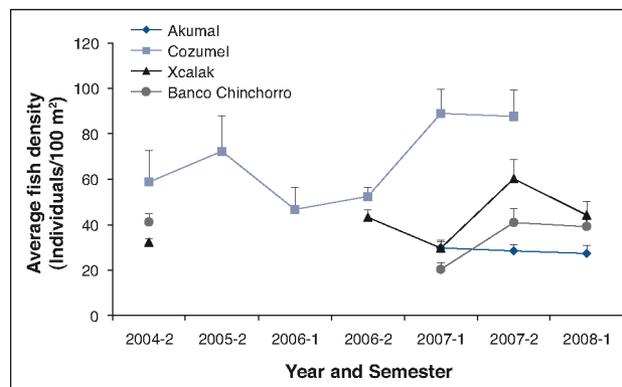
and the first surveys showed low coral cover (mean 10%) and high algal cover (mean 75%); this MPA is considered to be in a 'critical' status.

Coral cover in Bacalar Chico MPA, Belize has increased by 15% (from 2004–2006) with fluctuations in algal coverage. In 2004 this site was considered as 'alert' status; now it is regarded as being in good condition. The other MPAs showed a generalized trend of decreasing coral cover and increasing algal cover. Unfortunately, Hol Chan and Gladden Spit are regarded as being in 'critical' condition.

Monitoring in Guatemala has covered only 2 years with a tendency for a decrease in both coral and algal cover. The Sandy Bay MPA in Honduras was added to the monitoring program in 2007 with coral cover of 22% and algal cover of 50%. Other localities show decreases: coral cover on Cayos Cochinos dropped dramatically by approximately 50% (in 2004 it was 24% and only 12% in 2008).

### STATUS OF ADULT FISH AT MBRS SITES

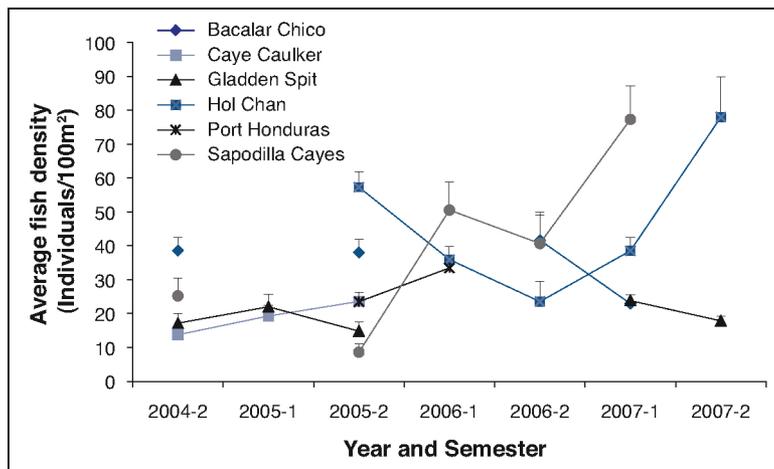
Fish monitoring showed temporal variation between the two semesters of the year along the MBRS region. There were no significant changes since 2006 in Akumal, Mexico which lacks legal protection and shows the lowest fish populations, whereas at Banco Chinchorro there was higher fish abundance with higher densities of families *Acanthuridae*, *Scaridae* and *Serranidae*. In Cozumel, immediately after hurricanes Emily and Wilma (late 2005) densities were above average (72/100 m<sup>2</sup>) probably due to reorganization of fish populations among the reef sites, higher activity of the fish and more large carnivores as a consequence of the reduction in refuge sites on the reef. Until 2006 the effects of the storms were evident with a reduction in fish abundance, however, there was an increase in density in the following year (2007) for families *Haemulidae* and *Pomacentridae*. Protection of the National Park in Xcalak had a positive effect on fish populations with increases since the nominal 2004 baseline. After Hurricane Dean (late 2007) hit the southernmost part of Quintana Roo, fish density increased above the average (60/100 m<sup>2</sup>) followed by a considerable reduction in early 2008 (44/100 m<sup>2</sup>). Values were still above the regional average but carnivores (*Serranidae* and *Lutjanidae*) remained scarce.



***Average fish density in Mexican MPAs during 4 years shows considerable variability, even between repeat sampling 6 months apart in the same year (for example, 2007-1 and 2007-2).***

The lowest densities of fish were at Gladden Spit and Caye Caulker in Belize with no significant changes in 2007. Nevertheless, at Bacalar Chico fish abundance was above the average during 2004, 2005 and 2006, but dropped in 2007 to less than the baseline average (22/100 m<sup>2</sup>).

Hol Chan and Sapodilla Caye had the highest densities in 2007 of 77/100 m<sup>2</sup>. These reefs have shown seasonal variations throughout the years with a major decline in fish abundance in late 2006. This reduction was probably due to the 2005 hurricanes and 2006 tropical storms but considerable increases were observed in 2007. Fish populations at Cayo Cochinos in Honduras showed a decreasing trend from 2004 to 2007; there were insufficient data at other Honduras sites for valid comparisons.



*Average fish density in Belize shows similar variations between seasons and years, as in Mexico.*

**STATUS OF MANGROVES, SEAGRASSES AND FISHERIES**

The mangrove forests throughout the MBRS region (7 localities in 4 countries: Banco Chinchorro and Xcalak, Mexico; Bacalar Chico, Belize; Rio Sarstun and Punta Manabique, Guatemala; and Omoa-Baracoa and Nueva Armenia, Honduras) are deteriorating as a result of human activities. The 4 species (*Rhizophora mangle*, *Laguncularia racemosa*, *Avicennia germinans* and the buttonwood *Conocarpus erectus*) are all affected. The highest mangrove density is at Arrecife de Xcalak, and the lowest was observed at Rio Sarstun. Forests across the region vary in maturation level from an average of young (5.8 m tall) to old (19.8 m tall), which reflects the history of hurricanes and storms in 2005. It is now acknowledged that these mangroves are particularly important in the region, especially for fisheries, thus continuing and increased monitoring is essential.

There are 7 seagrass species in the region with the dominant species being turtle grass (*Thalassia testudinum*) and manatee grass (*Syringodium filiforme*), along with *Halodule wrightii*, *Ruppia maritima*, *Halophila decipiens*, *H. englemanni* and *H. baillonis*. The seagrasses have a large distribution range and grow mainly in muddy estuaries, shallow sandy areas close to the coast, reef lagoons and around sand banks. However, distribution and density may vary

with the seasons, for example, seagrass beds are denser during April to June with clear, long days and high temperatures. Biomass, productivity, density, leaf area index, community composition and other related ecological parameters during 2004 and 2005 varied widely between 3 and 1596 g/m<sup>2</sup> in samples taken in different environments. Much of this biomass was below ground (roots + rhizomes) indicating that the beds may be healthy and biologically active, even when there were few shoots and leaves, and able to recover after damaging storms. These values also indicate that there is sufficient light for seagrass growth. However, increasing human coastal populations are threatening seagrass beds, especially coastal development, dredging and marina/jetty construction. Seagrass conservation will require careful management of rivers and estuaries and assessments of the economic and ecological value of these resources. However, management has insufficient information on seagrass beds in the MBRS as monitoring has not been continuous.

Fish resources are coming under greater pressures from increasing tourism development with some species, mainly groupers, snappers, grunts and jacks being targeted by local fishermen. Lobsters and conch are also very valuable fishery resources but information is insufficient for effective management. More research and monitoring on the trends in fishing activities in the MBRS region are required.

## CONCLUSIONS AND RECOMMENDATIONS

The region is showing a general trend of decreasing coral cover in MPAs and elsewhere with the largest changes between 2004 and 2005; there was an average loss of 7% coral cover, followed by annual losses of 2% in subsequent years. These decreases were measured in protected MPAs; which may underestimate more serious coral losses throughout the whole region. Thus management has apparently been insufficient to effectively attenuate the increasing negative stresses to the reefs. Furthermore, the overall reef condition, as measured by large scale assessments in 2006, found most sites in 'poor' to 'fair' condition as evaluated by the Healthy Reef's Initiative's Eco-health report card for the Mesoamerican reef.

While some of the reef declines may be caused by 'natural' factors like climate change and hurricanes, these are compounded by damaging human activities that are within the control of local managers (coastal development, fishing, etc). Management strategies will have to improve and adopt the 'precautionary principle' to prevent further damaging human activities that could push the remaining good and fair reefs over the edge into reef decline. We must manage to improve resilience so that the reefs can possibly recover from climate changes threats.

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### UPDATE ON CORAL REEF CONSERVATION AND MANAGEMENT IN BRAZIL

Coral reef protection, management and recovery measures have increased, after in Brazil joined the International Coral Reef Initiative as a country member in 2006. The Ministry of Environment is leading the establishment of a National Coral Reef Initiative with participation of NGOs and research and education institutions and several projects are under way: Coral Vivo project ([www.coralvivo.org.br](http://www.coralvivo.org.br)); the MMAS project ([www.conservation.org/mmases](http://www.conservation.org/mmases)); and the Recifes Costeiros project ([www.recifescosteiros.org.br](http://www.recifescosteiros.org.br)). The number of monitoring sites have increased with the creation of more fixed reef sites in locations already showing physical, biological and chemical damage, as well as in unaffected reefs. Although the number of protected areas has increased to 18% of the continental shelf, only 1% of these MPAs are fully protected. The Abrolhos National Marine Park (Eastern region), is one of those fully protected areas, including the area of the offshore Brazilian 'chapeirões'. The situation of oceanic reefs is better since Atol das Rocas and Noronha island are both fully protected MPAs (North-eastern region). Recently, the National Commission on Biological Diversity (CONABIO) resolved to increase the national marine and coastal fully protected areas to 10%. CEPENE (the Research Center of the Chico Mendes Brazilian Institute of Biodiversity) has approved a project to establish small no-take areas along the entire Coral Coast MPA based on results from the Projeto Recifes Costeiros; Conservation International Brazil has led similar initiatives in the Itacolomis Reefs. The success of those initiatives will, however, depend on capacity to overcome the chronic lack of enforcement, endless government changes in the environmental administrative bodies and difficulties with practicality of management plans. Destruction of the rainforests and mangroves, along with sedimentation mainly affects coral reefs close to the coast. Thus, recovery for these reefs will ultimately depend on a combination of actions such as recovery of riparian vegetation, conservation of coastal areas and best practices of land use. As overseas and national tourism is now growing in these areas it is hoped that conservation will be considered part of the attraction (from Beatrice Padovani Ferreira, [beatrice@ufpe.br](mailto:beatrice@ufpe.br), Universidade Federal de Pernambuco, Departamento de Oceanografia/ CTG; Zelinda Leão, [zelinda@ufba.br](mailto:zelinda@ufba.br); Ruy Kikuchi, [kikuchi@ufba.br](mailto:kikuchi@ufba.br), Universidade Federal da Bahia, CPGG/ IGEO).

## 19. STATUS OF CORAL REEFS OF THE LESSER ANTILLES: THE FRENCH WEST INDIES, THE NETHERLANDS ANTILLES, ANGUILLA, ANTIGUA, GRENADA, TRINIDAD AND TOBAGO

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### ABSTRACT

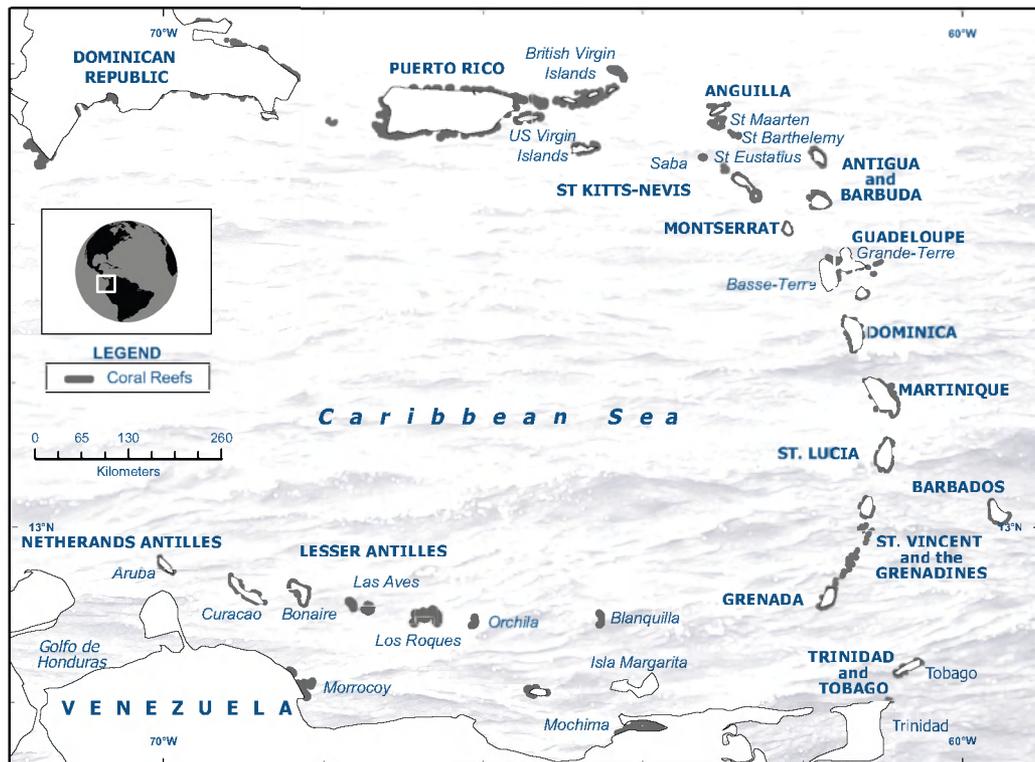
- The marine environments of these small and predominantly mountainous islands are all threatened by similar stressors: sediment runoff from the steep volcanic slopes; rapid development, particularly from the tourism sector; nutrient pollution from inadequately treated wastes and excessive use of fertilizers; over-fishing, especially from subsistence fishers; hurricanes and storms; and particularly climate change related coral bleaching and disease.
- The coral reefs remained relatively healthy until the early 1980s, but since then coral cover has been decreasing and algal cover increasing, with most of the reefs having lost more than half of their corals;
- Very severe coral bleaching affected all these islands in 2005, when abnormally warm water temperatures exceeding 29°C and up to 31°C sat over the coral reefs from mid May to mid November. Many island states reported that more than half of their corals bleached with a large proportion of these subsequently killed;
- In 2006 many corals were still bleached or were infected with coral disease, such that coral losses continued, with many countries reporting losses of about 50% of their previous coral cover;
- Reef fish communities were not affected by the bleaching but have progressively declined through over-fishing and habitat destruction;
- Most of these eastern Caribbean Islands lack sufficient capacity for coral reef monitoring and effective management, and many of the MPAs have remained as 'paper parks';

- The most active monitoring and management is in the Netherlands Antilles and the French West Indies, following recognition that well managed tourism will support reef conservation in the long-term;
- The Caribbean Challenge is aimed at rectifying these problems by the countries cooperating to conserve 20% of their coastal resources in networks of MPAs by 2020.

## INTRODUCTION

The first observations on the Lesser Antilles report idyllic conditions, for example, Father du Tertre described Guadeloupe in 1670 as *“I am very certain that during the first ten years after the isle was inhabited, we pulled out (from the sea) every year more than three to four thousand turtles, a very large number of manatees and we still pull out every day quantities of them, and it will continue until the end of the world without depleting them.”* The first scuba divers to Guadeloupe in the early 1950s suggested that the reefs were in ‘pristine’ condition.

The Lesser Antilles are a semi-circular chain of islands from 18°N to 11°N and 59°W to 70°W and form the western boundary to the Caribbean Sea. Anguilla is the most northerly at 18°35'N; the French West Indies (FWI) lie between 18°00' and 14°20'N and consist of the islands of Martinique, Guadeloupe, La Désirade, Marie-Galante and Les Saintes, St. Barthélemy and the French part of St. Martin/Sint Maarten; Barbados is the most easterly at 13°10'N and 59°30'W; Tobago is the most southerly with coral reefs at 11°10'N to 60°49'W; and the main Netherlands Antilles are between 70°03'W and 68°10'W.



Most of these islands are volcanic and mountainous with a narrow shelf before dropping into deeper water. Corals grow as fringing reefs on the eastern, oceanic sides and as broader fringing reefs with occasional platforms. These reefs are, however, subject to considerable input of sediments and nutrients from the erosion of the volcanic soils. In contrast, Anguilla, one of several islands on the Anguilla Bank in the far north, is an uplifted fossil coral reef surrounded by fringing and patch reefs and offshore cays.

Tourism is a major economic contributor in the Lesser Antilles, developed mainly on the basis of clean water and coral reefs. The other major economic activity is fishing, both subsistence and commercial for grouper, snapper, lobster and conch. Thus the economies of these islands are heavily dependent on the maintenance of their coral reefs and other coastal resources.

The following sections will cover these islands and reefs on the map in from north to south along the pearl-like chain of the Lesser Antilles.

### STRESS AND DAMAGE TO REEFS OF THE LESSER ANTILLES

The same Caribbean-wide stresses threaten the reefs on these islands, especially inappropriate watershed modification which has resulted in increased erosion of sediments and release of nutrients from these mountainous islands. Over-fishing and unsustainable coastal development occur on all islands as human populations increase and tourism expands. There have also been major disease outbreaks, hurricanes, increased seawater temperature, and changes in sea level and water chemistry. The magnitude of these stresses and the responses by the island governments vary but not to a great extent. The major natural and human stresses that have resulted in the decline of Lesser Antilles reefs are:

- **Human stresses:** excess sediment and nutrient discharges into coastal waters is occurring from deforestation for agriculture, poorly managed coastal development and mangrove clearing. This is particularly affecting enclosed bays and lagoons. Elevated nutrient loads also result from poor wastewater treatment and overuse of fertilizers; the results are seen in the proliferation of the brown algae *Dictyota* and *Lobophora* in sheltered areas and *Sargassum* and *Turbinaria* on exposed outer slopes. Contamination of coastal waters by various pesticides is now evident in many areas, especially in Martinique and Guadeloupe, but the potential impacts are unknown.
- **Sea surface temperature increases:** Most years it is low level, except in September when chronic coral bleaching occurs when temperatures exceed 29°C for a short time. There was minor coral bleaching in 1984, 1987 and 1998 when other regions in the Caribbean had severe bleaching. But corals in the Lesser Antilles were severely damaged during the hot summer of 2005.
- **Hurricanes:** There have been 5 hurricanes since 1989 that have directly affected the region: Hugo in 1989 in Guadeloupe; Luis and Marilyn (1995) and Lenny (1999) damaged Saint-Barthélemy and Saint-Martin; Dean in 2007 devastated the reefs of Martinique but caused little damage to Guadeloupe. Damage results from the huge waves and massive quantities of sediments and nutrients washed out by torrential rains. Often there are short-lived algal blooms after hurricanes.

## Anguilla

We have not reported previously on the reefs of Anguilla; the only previous study was by the Bellairs Institute of Barbados in 1990; since 2004 new data have been collected by the Department of Fisheries and Marine Resources. Prior to 1980, the reefs around Anguilla were largely pristine with high coral cover, although there are no quantitative data. Anguilla suffered a massive *Acropora palmata* die-off in the 1980s, probably caused by white band disease. The Bellairs group reported coral cover between 4% and 23% at 8 sites around Anguilla in 1990 with the highest cover on the offshore cays. Hurricane Luis in 1995 caused an almost total loss of mangroves, halved seagrass cover and severely damaged corals. Octocoral cover went from 25% to less than 5% (83% loss); *Monstaraea* sp. cover dropped from more than 25% to less than 2% (95% loss) and losses in other corals ranged from more than 15% to less than 3% (89% loss). The offshore banks still retained some intact coral communities but hurricane Lenny in 1999 caused further damage. The current threats to reefs include: the loss of *Diadema antillarum*; over-fishing; nutrient enrichment; coastal development; coral bleaching; and coral diseases.

### CORAL REEF STATUS IN 2008

Anguilla sat in the 2005 'hot spot' from June to October, however, the extent of coral bleaching is unknown. Local dive operators reported bleaching but monitoring in 2007 was too late to identify specific bleaching impacts. Baseline data collected in 4 Marine Parks showed coral cover between 0.5% and 24.5% across a variety of reef habitats but low coral cover was more common, averaging 9.5%. Offshore sites had the highest cover, with lower macro-algal cover and higher relative biomass of fish. The coastal Shoal Bay – Island Harbour Marine Park had high cover of fleshy macro-algae, mostly *Dictyota* sp. The low coral and high algal cover are presumed to be due to over-fishing of herbivores and low *Diadema antillarum* populations, as well as increases in the nutrient loads from coastal developments. In late 2007 the existing corals were predominantly healthy with 73% to 95% of coral tissue being healthy, and 45% to 84% of coral colonies showing dead areas. There was 7% of coral tissue bleached at one site. Thus in 2008 reefs on the south coast of Anguilla have very low coral abundance, with some areas having high cover of macro-algae. Coral recruitment appears low in all locations. *Diadema antillarum* populations seem to be recovering, although distribution is still rather patchy. Expert opinion considers that the Anguilla reefs are continuing to decline from the status reported in the 1990s.

**Socioeconomic Impacts and Management Responses:** Coral reefs are recognised as important in Anguilla's economy, especially through fishing and tourism. Thus the Government has developed a long-term marine monitoring program to assist in developing coastal management plans that will include sections with strong coral reef protection including no-take zones in shallow reef areas, and a review of the fisheries legislation.

## Antigua

There have also been no detailed reports on Antigua and Barbuda reefs in previous Status reports. These reefs were described previously as 'extensive' and 'exceptional in their variety', but little quantitative information was reported previously. The following information follows rapid assessments between 2006 and 2007 of patch and bank-barrier reefs.

## CORAL REEF STATUS IN 2008

Reefs were assessed at 2–10 m depth on 16 reefs in Antigua (13 in the NE of Antigua; 3 at Cade's Reef, SW); and also at 20–25 m in the NE and SW. Much of the reef structure consists of large, interlocking branches of dead elkhorn coral (*Acropora palmata*), indicating previous luxuriant growth. There are 32 species of stony corals covering 2–19% of the reef benthos (mean 6.7%;  $\pm$  4.6 s.d.); cover on deep reefs was less than 3%. The most abundant corals were *Porites astreoides* (25% of all colonies), *Agaricia* spp. (12%), *Montastraea faveolata* (9%), *M. annularis* (8%) and *M. franksii* (7%). *Acropora* corals (mean cover 1.5%  $\pm$  3.3) were observed at 8 of 16 sites, including *A. palmata*. *A. cervicornis* and *A. prolifera* observed together at 2 sites in the North Sound region. A few colonies of both *A. palmata* and *A. cervicornis* were found at 22 m depth in the NE section of Antigua. There was low abundance of recruits and juvenile corals (< 2 cm in diameter; 0.9 recruits/m<sup>2</sup>), mostly *Porites* (25% of juveniles), *Montastraea* (14%) and *Agaricia* (12%).

There was high cover of fleshy (*Dictyota*, *Lobophora*) and calcareous (*Halimeda*) macro-algae, ranging from 9–58% (mean of 33.3%  $\pm$  16.4). Other dominant groups included turf (31.5%  $\pm$  12.7), crustose corallines (6.2%  $\pm$  6.8) and cyanobacteria (5.8%  $\pm$  7.3). The cover of cyanobacteria reached more than 25% at 2 sites with mats of *Lyngbya* smothering *A. cervicornis*.

Average recent mortality was 1.1% ( $\pm$  0.9), which is lower than the regional average (2.6%) from >800 sites in the AGRRA database. However, this was nearly double the 0.6% value recorded in 2005. Only 1.1% of colonies showed any disease, with yellow blotch being most common (on more than 20% of *Montastraea* colonies) in December 2006. Similarly, bleaching in 2007 was rare with 2.5% of colonies affected, compared to 22.3% of colonies in August 2005. The 2005 bleaching appears to have seriously reduced coral cover from 16% to the 6.7% coral covered recorded in 2007 (2005 data from Brandt et al).

## REEF CONSERVATION IN ANTIGUA

Coral reefs and their associated resources are essential to the economic sustainability and growth of Antigua and Barbuda. Several MPAs have been established: Diamond Reef Marine Park; Palaster Reef Marine Park (both gazetted in 1973); the Cades Bay Marine Park (gazetted in 1999); and the Codrington Lagoon and the North Sound (gazetted in 2005). However, there is little active management of the resources.

## STRESS AND DAMAGE TO REEFS

The government of Antigua and Barbuda is aware of risks and is developing resource management and sustainable development plans. A Global Environment Facility project in 2008 is developing a Sustainable Island Resource Management strategy for 'ecosystem functionality and biodiversity conservation within a landscape that enhances sustainable livelihood options and opportunities for sustained economic development'. Stresses causing the largest impacts on coral health are: macro-algal, cyanobacterial, and sponge competition; coral diseases; and sedimentation/nutrients. Algal overgrowth of shallow water corals by *Caulerpa*, *Lobophora*, *Dictyota*, *Halimeda* and the cyanobacterium *Lyngbya* is clearly evident. Crustose coralline algae were also out-competing corals, especially *Millepora* spp. Bioeroding (*Cliona*) and encrusting sponges are also out-competing corals on patch, shallow and deep bank reefs. In

late 2006 there was >20% prevalence of coral disease (mainly yellow blotch and white plague) on shallow, massive *M. faveolata* and *M. annularis* colonies >50 cm, probably a consequence of the 2005 bleaching event. Increased sedimentation is also damaging shallow corals with many colonies covered by a thin layer of fine, clay-like sediment, especially near dredged areas. There were parallel signs of recent coral death and coral recovery on remnant branches of dead *A. palmata* which provides good habitat for corals, fishes and reef invertebrates.

## CONCLUSIONS

Corals on Antigua have been recently damaged by local and regional disturbances, but there are still healthy corals and the species richness is high. These reefs will recover provided surviving parent corals that can provide larvae are protected and the important algal grazers, especially fishes, are not further reduced. Finally, there are surviving populations of the 3 Caribbean *Acropora* species in NE Antigua. These corals have been drastically reduced everywhere in the Caribbean and have been recently listed as a threatened species in the USA. Previous large stands of *A. palmata* are gone, but surviving colonies of *A. palmata* occur on shallow and deep reefs, including new recruits. *A. cervicornis* is ubiquitous on shallow and deep bank reefs and is actively recruiting in many habitats. This may indicate a good chance for recovery as these branching corals grow quickly and can expand through fragmentation.

## Grenada

Most of the data from Grenada have been collected from the 1980s on reefs on the southwest coast close to Grand Anse and St. George's; the 'tourist belt'. However, not all these data are available. Tourism is a major contributor to the economy and continues to grow rapidly with increasing infrastructure development. Reefs on the south-west side are heavily used by locals and visitors with more than 80% of all recreational diving occurring there.

Surveys in 2006 and 2007 identified 33 hard coral species, with the most common being *Porites porites* followed by *P. astreoides* and *Montastraea annularis*. Macro-algae, especially *Dictyota* and *Halimeda*, comprise the largest component on the bottom at 9 sites in south-west Grenada with mean cover from 36.5% ( $\pm 0.8\%$ ) to 53.2% ( $\pm 1.2\%$ ). Hard corals were the second most common component, ranging from 23.8% ( $\pm 0.9\%$ ) to 38.1% ( $\pm 1.2\%$ ); and the sea urchin, *Diadema antillarum* was either rare or absent.

Indiscriminate anchoring by boat operators and spear fishing pressures on algal-grazing fish were considered as the two biggest human threats to coral reefs on Grenada's southwest coast; storm surges and hurricanes were the largest natural threats. The major threats to coral reefs are coastal development and poor land use practices on the east and south-east coasts.

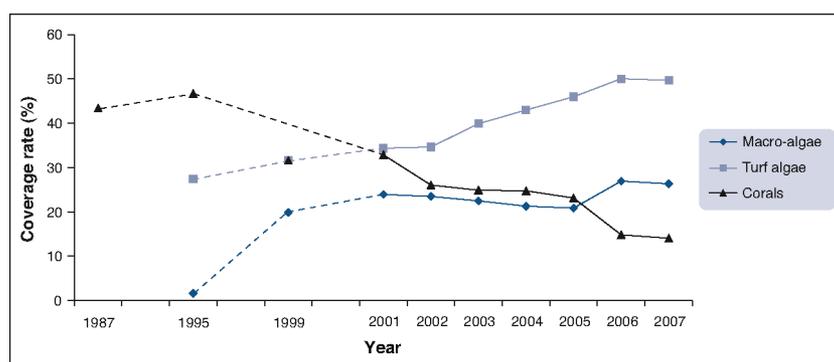
## CORAL REEF STATUS IN 2008

Macro-algae remain the largest component of benthic cover on south-west reefs, followed by hard coral cover, which declined at some sites from 23% to 38% in 2007 to 6% to 20% in 2008. There is an urgent need to manage spear fishing on reefs along the south-west coasts; and ensure that developers engage in good land use practices on the east and south-east coasts. The Government of Grenada is attempting to strengthen management of Grenada's near shore marine resources and declared a new MPA in September 2008 on the Grenadian sister island of Carriacou. The addition of the Sandy Island Oyster Bed MPA brings the total of MPAs in Grenada to three.

## The French Caribbean Islands

The French West Indian islands of Martinique, Guadeloupe (including Désirade, Marie-Galante and Les Saintes), Saint-Barthélemy and French Saint-Martin all have coral reefs. There are two barrier reefs along the east coast of Martinique and the north coast of Guadeloupe, and other coasts have fringing reefs on the windward and leeward coasts. The small islands near Saint Barthélemy and Saint-Martin have poorly developed fringing reefs, but extensive seagrass beds on the shallow, sandy island shelf. The largest area of mangroves in the Lesser Antilles is in Guadeloupe, but these have been largely destroyed by land reclamation.

There are 834 000 people in the French West Indies and an additional 1.2 million tourists every year; thus tourism is the important economic activity based largely on 'healthy' coastal resources. The tourists come to use glass-bottomed boats and kayaks, go water skiing, surfing, sailing, fishing and particularly go scuba diving with one of 80 scuba clubs in Guadeloupe and Martinique. Most diving is on the Caribbean side, for example, about 100 000 divers visit the Îlets Pigeon in Guadeloupe each year. There are 3 MPAs in Guadeloupe and one each in St. Barthélemy and St. Martin, as well as several non-permanent no-take zones in Martinique.

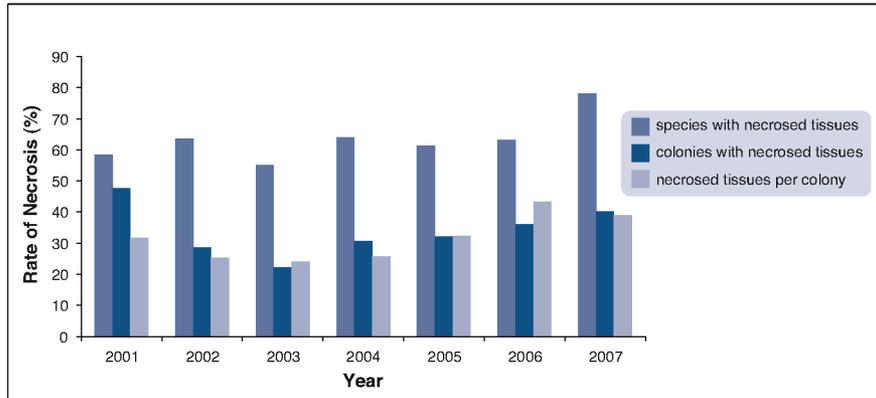


*The cover of live corals on French West Indies reefs combined shows a steady decline since 2001 with an apparent initial baseline around 20–25%; in parallel there have been increases in total algal cover (turf and macro-algae). Occasional monitoring in 1987 and 1995 indicate that 20 years ago coral cover was above 40%, indicating that coral losses are more serious than recent monitoring shows. The corals are being replaced principally by bare rock covered with unattractive low turf algae.*

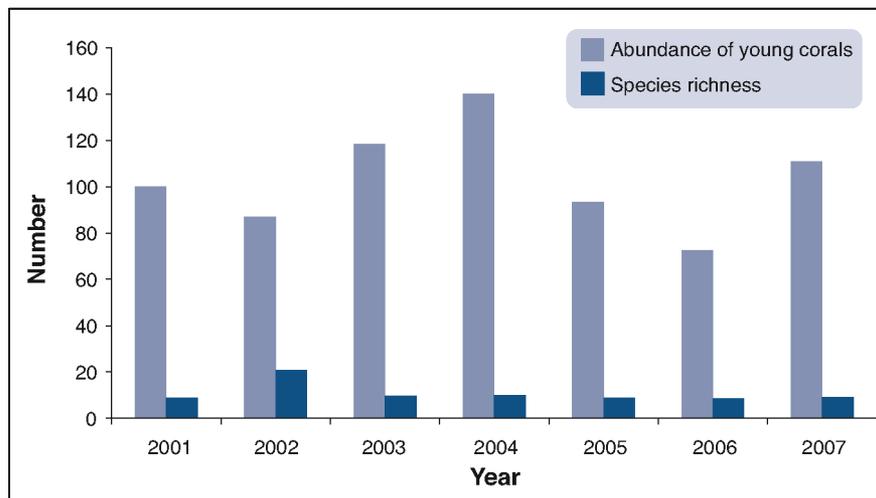
### CORAL REEF STATUS IN 2008

The first scientific observations of the coral reefs of Martinique and Guadeloupe Islands in the 1970s showed that reef health was beginning to decline due to a combination of natural and human stresses. When these two islands were mapped in 1996, only 15–20% of their reefs contained flourishing coral communities, and coral cover on Guadeloupe was assessed at 14% on reef flat areas and 45% on outer slopes. For example, coral cover on Îlets Pigeon dropped from 46% in 1995 to 26% in 1999, 11–56% of coral colonies showed some disease, and 11–56% of the surviving corals had some dead areas. There were similar observations on Martinique. The graph below shows the steady decline in coral cover and parallel increase in algal cover from monitoring program (every 6 months) established in 2001 as part of the GCRMN.

An exceptional increase of sea surface temperatures in the Caribbean caused massive coral bleaching on the reefs of the FWI in 2005, and significant delayed mortality due to coral diseases throughout 2006. This is seen in the sharp drop in the graph below. Surveys also show a decline in the health of the corals; for example the incidence of diseased coral colonies has been steadily increasing since 2003.



*The incidence of coral diseases has remained relatively high over the last 7 years in proportions of species with necrotic tissues, the number of colonies with diseased patches and the average surface of necrotic tissues per colony. The incidence of disease has risen steadily from the lowest point in 2003.*



*This graph shows the numbers of new coral recruits which is an effective measure of coral reef health. There was a drop in recruits after the bleaching losses in late 2005, but by 2007 the numbers were approaching pre-bleaching levels (average of 9 reef sites). The number of species recruiting per season is very stable (8 to 11 species per 30m<sup>2</sup>).*

Fish populations have remained largely stable since 2001 with similar numbers of species, total biomass and a consistent fish community structure. This is probably because the three-dimensional structure of the reefs has not changed significantly. However, species richness has increased in the Saint-Barthélemy MPA; similarly fish biomass has increased in the Pigeon Island MPA. A worrying trend is a significant decrease in the populations of algal grazing fishes (herbivores) which indicates over-fishing with traps and nets.

### **STATUS OF MANGROVES, SEAGRASSES AND FISHERIES 2008**

There has also been degradation of seagrass beds and mangrove forests throughout the FWI. The extensive seagrass beds are nursery areas for many commercial species of invertebrates and fishes, but they are paying a heavy price from continued development of harbours, marinas, artificial beaches for hotels, sand mining and especially anchor damage from yachts and cruising and freighter ships. Guadeloupe has prohibited the use of seine nets to protect the shallow seagrass habitats of juvenile fishes. There are extensive mangrove forests in the bays of Martinique and Guadeloupe has the largest forest area in the Lesser Antilles. However, only a few trees remain in St-Martin and St-Barthélemy. The mangrove forests have also been devastated by economic development, especially through land reclamation for airports, industrial areas, hotels, marinas, etc. The 2500 registered professional fishermen land about 8000 tons of seafood in Martinique and 10 000 tons in Guadeloupe, with 60–75% taken from the reefs. Ciguatera (fish toxin) has significantly limited commercial fishing in St-Martin/St-Maarten and St-Barthélemy. Parrotfish (scarids) constitute the most important fish family captured by traps or nets, however, this is a potentially worrying sign as algal grazing fish play a major role in controlling macroalgal domination of coral communities; this will affect most reefs in the French West Indies.

### **CONCLUSIONS AND RECOMMENDATIONS**

The corals reefs of the FWI have shown a long-term decline of their coral communities, shifting from coral to algal dominated communities. This phenomenon is probably due to multiple causes: eutrophication of coastal waters; high rate of sedimentation; chemical pollution; and over-fishing. Trends in biotic indices like the importance of necroses on the coral colonies and the recruitment of juveniles are also not encouraging. After several alerts in 1984, 1987 and 1998, the 2005 bleaching had a major impact on the coral communities of FWI resulting in a decrease of about 40% of the coral cover on the reefs. If such events are repeated too frequently the consequences will be a dramatic decline of the reefs. The most impacted coral communities were those which were also subjected to high levels of anthropogenic stress. Rapid action against these various local human threats on the coral communities is recommended to retain coral resilience to bleaching effects. Such control would not only suppress the continuous slow decline of reef health, but also diminish the impact of the temperature anomalies due to global warming and favour the recruitment of new coral settlers. It is recommended that the long term monitoring program be continued to ensure that management is provided with valid information to make sound decisions to conserve these reefs, which were severely damaged during the 2005 bleaching event, with losses of 30–50% in coral cover.

### **The Netherlands Antilles**

There are two distinct island groups in the Netherlands Antilles. The small oceanic islands of Bonaire and Curaçao 70 km north of Venezuela are in the path of persistent trade winds,

hurricanes are rare, and the islands have an arid climate. Bonaire and Curaçao have continuous fringing reefs around them especially on the leeward coasts. The wetter, volcanic Windward Islands (St. Maarten, Saba and St. Eustatius) form the second group, and are often affected by hurricane swells and winds. They have narrow shelves and limited reef growth along their windward coasts. St. Eustatius has true calcareous reefs plus corals growing on volcanic rock, whereas the only true reefs on Saba are on the east of the island. St. Maarten (half Dutch and half French) has rapid and seemingly unmanaged tourism expansion, and as a consequence, the reefs have been damaged by pollution, deforestation, sedimentation, eutrophication from sewage, recreational boating and anchors. The Saba Bank is a very large submerged atoll with actively growing reefs, to the south-west of Saba.

Tourism is the main economic activity on all islands, especially Bonaire, which is almost completely dependent on dive tourism. Tourism is growing rapidly on Curaçao. All islands support small-scale artisanal reef fisheries, and the Saba Bank has a major lobster fishery. All un-protected reefs of Bonaire and Curaçao suffer from over-fishing, and recently Bonaire established no-fishing zones as a measure against over-fishing.

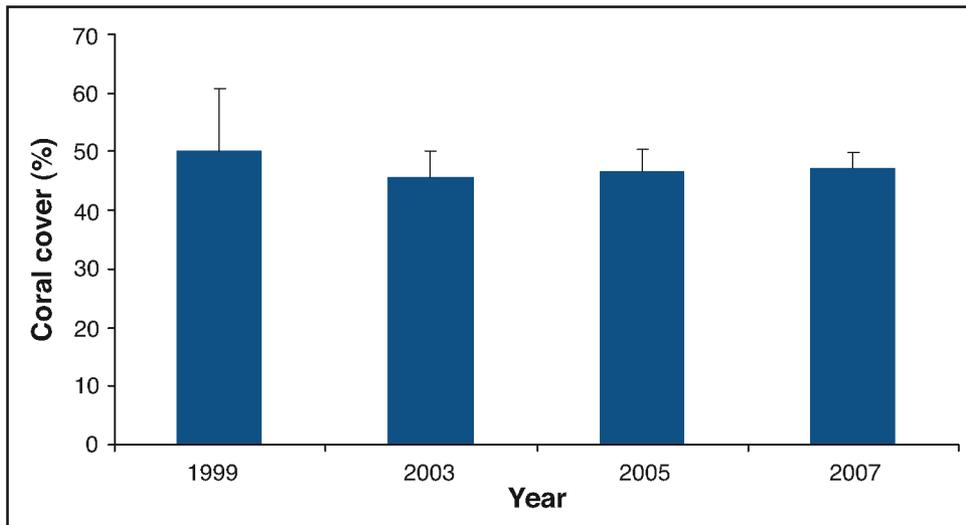
Although considered healthy compared to other Caribbean reefs, the reefs of Bonaire and Curaçao have been steadily deteriorating since the early 1980s (and even longer according to anecdotal evidence); the other islands also appear to be deteriorating. Bleaching in 2005 severely damaged the Windward Islands reefs, but spared the reefs of Bonaire and Curaçao. The most important threats to the reefs on the islands are coastal development and over-fishing for Bonaire, Curaçao and St. Maarten, and sedimentation from land erosion due to bad land management on St. Eustatius and Saba. A Netherlands Antilles coral reef monitoring node was established in 2005 building on the efforts of the island MPA managers and the help of volunteers. Water quality monitoring was added around Bonaire and Curaçao in 2006 to assess nutrient enrichment from coastal development.

### **CORAL REEF STATUS IN 2008**

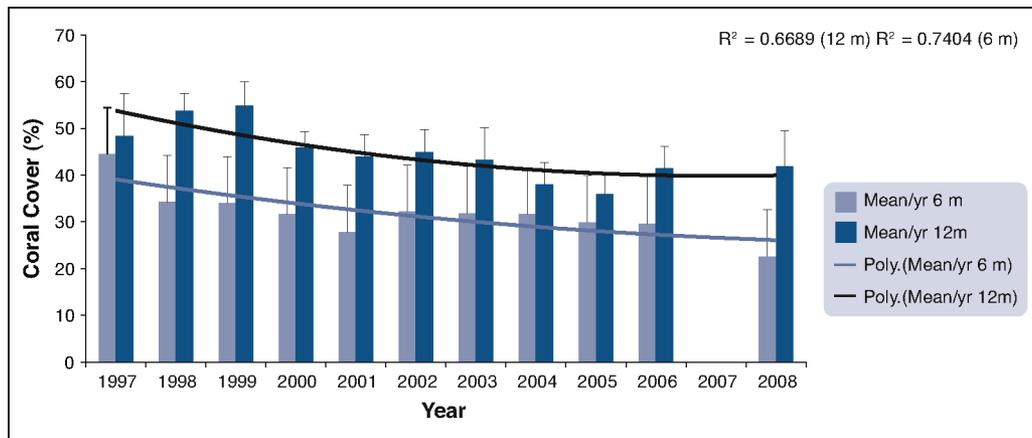
The reefs of Bonaire and Curaçao remain predominantly healthy, with relatively stable coral cover; but strong declines were reported in the 1980s and 90s when disease and the loss of *Diadema antillarum* killed many corals. The last major impact was from the large waves of hurricane Lenny in 1999, which smashed corals down to about 10 m depth; subsequent coral diseases compounded the damage. Recent measures of nutrient concentrations on Bonaire point to threats of eutrophication and macro-algal overgrowth; the situation on Curaçao is worse with nutrient levels beyond accepted threshold values and higher cover of macro-algae.

Monitoring on Bonaire by AGRRA indicates that the reefs remain among the best in the Caribbean, with nearly 50% average coral cover and increasing juvenile coral densities (from 20 in 2005 to 39 individuals per m<sup>2</sup> in 2007). However, there are some potentially troubling trends, as macro-algal cover has doubled from about 4% in 2003 to 8% in 2007, while parrotfish biomass and bite rates declined. In addition, there are increases in damselfish populations and declines in coralline algae. These point to possible reduced recruitment of reef corals and increasing macro-algal abundance. Some carnivorous fish populations (lutjanid snappers) are stable but there is a continual loss of groupers and barracuda. Abundance of the algal grazing urchin, *Diadema antillarum*, is increasing with densities of up to 1.79 individuals per m<sup>2</sup> at one site.

Curaçao experienced large declines of coral cover during the 1990s; but cover has been relatively stable over the last 10 years at about 40% at 12 m depth. The incidence of coral disease dropped below 10% in the late 1990s, and has generally been below 5% since 1998. There are no clear trends in macroalgae cover or coralline algae. Large *Acropora cervicornis* stands covering hundreds of square metres are reappearing; for example, one stand established itself in 3–4 m depth after hurricane Lenny cleared the cemented base-rock in 1999. This stand re-established itself again after being completely levelled during hurricane Ivan in 2004: the colonies are about 60 cm high. *Diadema antillarum* abundance is increasing, particularly in lagoon entrances, with densities of up to 3 individuals per m<sup>2</sup>.



**Coral cover on Bonaire has remained stable around 50% at the same locations since 1999 (data from Kramer and Bischoff, 2003 and Steneck, 2008).**



**Coral cover has remained relatively stable over the past 10 years as measured on duplicate 50 m transects in 6 locations on Curaçao, surveyed twice a year. Polynomial lines represent the best fit for 12 m and 6 m depth respectively, regression values are also given.**

**St. Eustatius:** The reefs were hard hit by the 2005 bleaching event, with 70–80% of coral colonies bleached. Subsequent mortality resulted in a loss of the original live coral cover from about 30% to less than 15% in 2008; a 50% decrease. Macro-algal cover increased from about 40% in 2005 to almost 60% in 2008.

There are no recent data for Saba and St. Maarten, however, there are reports of large coral cover losses in 2005. There are established species lists of hard and soft corals, macro-algae, and fishes for the extensive and rich reefs on the windward eastern and southern edges of the Saba Bank, but no recent monitoring data. Comparison of photographs taken on the Bank in 2002 and 2007 show at least an 80% decline in coral cover, probably due to losses during the 2005 bleaching event.

### **STATUS OF MANGROVES, SEAGRASSES AND FISHERIES: 2008**

The main mangrove and seagrass areas on Bonaire are in Lac Bay, a Ramsar site. An island government decision to allow development adjacent to this area was overturned in 2007 to protect these wetlands of international importance. These protected mangroves are home to a thriving, carefully guided, kayak tour industry. Mangroves on Curaçao remain under threat and are slowly being reduced by coastal development. St. Maarten has some mangrove stands, but these are being quickly eradicated by uncontrolled tourism development. The situation with seagrass beds is similar. St. Eustatius has significant seagrass beds which are essential food for visiting populations of nesting turtles.

**Fisheries:** Bonaire established two no-take fish reserves within the Bonaire National Marine Park in 2007 in response to declining predatory fish like groupers. The Curaçao 2008 fisheries law plans to establish fish reserves; but no reserves have been designated. The reefs appear seriously over-fished and groupers and other larger predators are extremely rare; but there are no quantitative data.

### **CONCLUSIONS AND RECOMMENDATIONS**

The reefs of Bonaire and Curaçao are still relatively healthy, compared to other parts of the world, which increases their value as a dive tourism destination. This presents an opportunity for Bonaire and Curaçao, provided they safeguard these delicate resources with effective wastewater and fisheries management. In Curaçao, a reduction in pollution at the most polluted sites is necessary as well as introducing nature conservation legislation for effective coral reef management. Currently there is increasing pressure by developers to cash in on the booming tourism industry.

Saba and St. Eustatius have good coral reef management systems, whereas St. Maarten urgently needs to pass legislation to manage their coral reefs so as to improve resilience for better recovery after the large coral declines in 2005. There is an urgent need to manage the fishery resources of the Saba Bank with effective monitoring and enforcement, and so that it can be used as a model to study coral reefs that are remote from coastal influences.

### ***Trinidad and Tobago***

These are the most southerly of the eastern Caribbean islands, on the edge of the South American continental shelf. Trinidad has marginal coral communities due to the influence of the Orinoco

River, with only sediment tolerant coral species (*Siderastrea* and *Porites*). Tobago, however, is more remote from the large rivers and has patch and fringing reefs along about 90 km of the coastline. The threats to Tobago reefs are primarily nutrient and sediment runoff from land clearance and coastal development, sewage pollution and climate change. Many coral colonies were damaged during the 2005 mass bleaching event; and many of those that recovered were subsequently affected by coral disease. The Buccoo Reef Trust and the University of the West Indies, with funding from the Global Environment Facility, started monitoring in 2007 at the Buccoo Reef Marine Park; designated in 1973, it has also been a Ramsar site from 2005. The Marine Park covers approximately 13 km<sup>2</sup> with a complex mix of seagrass beds, mangrove forests and patch reefs.

There are many regulated tourism activities as well as illegal fishing and reef-walking. A management plan was developed in 1995 but was never implemented. Although the Buccoo Reef Management Committee was established in 2004 to implement the management plan of Park activities, the Committee has been largely ineffective at controlling damaging activities. The International Coral Reef Action Network, with funding from the United Nations Foundation, has now implemented a management and education program to improve management capacity by facilitating training, exchange and networking opportunities.

### CORAL REEF STATUS IN 2008

Coral cover at the 11 permanent monitoring stations ranged from 26% at Sisters Rocks in the Caribbean to 3% on Bulldog Reef in the Atlantic. Caribbean reefs are primarily hard coral-gorgonian dominated, while macro-algae and sponges dominate the Atlantic side. Coral species diversity is higher on the Caribbean side (Kariwak to Pirates Bay) than on the Atlantic coast. Mean coral cover at 10 m depth was 15%, with macro-algae (18%), gorgonians (12%) and zoanthids (6%). Massive species constituted the largest proportion of corals (*Montastrea faveolata*, 35%; *Siderastrea siderea* 10%; *Diploria strigosa* 9%, and *Millepora* 15%).

Mean coral cover at 7 and 12 m depths dropped from 21% in 2005 to 15% in 2008 on the north-western side; most likely due to disease outbreaks following the 2005 bleaching event. Large swells in March 2008, damaged the shallow reefs on the Caribbean coast, and there is widespread coral disease, especially yellow band and dark spot diseases. Aspergillosis is infecting more than a third of all gorgonians (sea fans). White plague levels are particularly variable in summer, whereas black band disease is generally low. The few remaining elkhorn coral (*Acropora palmata*) stands are susceptible to white pox and patchy necrosis. The reefs on Tobago have become dominated by macro-algae, particularly downstream of the major towns on the Atlantic side where algal cover was high (34–65%) and apparently associated with nutrient and sewage pollution, especially during the rainy season.

### REEF FISH AND INVERTEBRATES

Grouper (*Serranidae*) densities were generally low (<90 fish/hectare) with only two species (*Cephalopholis cruentatus* and *C. fulva*) comprising nearly 90% of all sightings on the north-western side. Nassau Groupers (*Epinephelus striatus*) are considered to be locally extinct and snapper (*Lutjanidae*) densities were also low (70 fish/ha). The total biomass of the 3 targeted families, groupers, snappers and grunts (*Haemulidae*), was 276 kg/ha on reefs between Buccoo and Castara. In the north-west, parrotfish densities (~950 fish/ha) and surgeonfish (~575 fish/

ha) are less depleted than elsewhere in the region. Like Curaçao, *Diadema antillarum* were not observed at 10 m monitoring stations, however, *Diadema* densities (75 urchins/ha) at 7 m and 12 m on the north-western side of the island suggest populations are increasing. Coral recruitment appears to be limited by low levels of macro-algae, a predominance of unstable rubble substrata and possibly other environmental factors. Densities of queen conch and spiny lobster numbers remain low (<2–3 individuals/ha); and there are no management policies to protect existing populations.

## CONCLUSIONS AND RECOMMENDATIONS

The prevalence of algae on Tobago's reefs has been increasing since the 1980s, in parallel with significant coastal development and population growth. Sewage treatment is inadequate and facilities are not maintained, and sedimentation rates are increasing. These stresses are probably the cause of reduced live coral cover and high macro-algal cover. Although the Reefs at Risk assessment regarded Tobago's reefs as over-fished, relatively high grazing levels by parrotfish and surgeonfish are controlling algal growth in the north-west. These results are encouraging, but there have been insufficient studies. The reefs are also affected by sediment from inland development and deforestation in the watersheds. There has been little coral bleaching since 2005, but there are high levels of coral disease on the reefs, especially yellow blotch disease affecting the dominant *Montastrea faveolata*.

The World Resources Institute estimated that the coral reefs on Tobago provided approximately US\$120 million or 42% of the island's GDP in 2006, through tourism, recreation, fisheries, and shoreline protection. This highlights the economic need to maintain coral reef health on Tobago. For example, baseline mapping is being extended to other parts of the island.

- A long-term monitoring program is needed to build on baseline mapping surveys and increase monitoring from the current 12 fixed stations; agencies are re-establishing Reef Check surveys around the island.
- Damage from land-based sources of pollution should be reduced through more effective watershed and coastal management, especially by raising public awareness of the damage and encouraging behavioural changes. Some communities are replanting a major watershed to protect downstream reefs on the north-western coast.
- Poor management capacity is hindering reef conservation, therefore a park manager and sufficient reef patrol officers are urgently needed to enforce regulations in the Marine Park. Draft legislation for Environmentally Sensitive Areas that has been dormant for 4 years needs to be ratified, and the Management Committee given greater authority and financial autonomy to control damaging activities and implement the recommended zoning plan.
- Finally, extensive public education and awareness campaigns are needed to ensure that all users appreciate and understand the value of these important coastal resources, and consideration should be given to establishing community managed marine protected areas elsewhere on the island.

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## CCCC - CARIBBEAN CHALLENGE TO CONSERVE CORALS

Caribbean countries have taken up the challenge from Micronesia and launched the 'Caribbean Challenge' to conserve biodiversity. The Government of Grenada announced a plan to protect 25% of its land and sea areas by 2020 at the Convention on Biological Diversity meeting in Brazil in 2006. Following this, the Prime Minister of the Bahamas, Hubert Ingraham, launched the Caribbean Challenge at the CBD 9<sup>th</sup> Conference of the Parties in Germany in May 2008 with the Dominican Republic, Jamaica, Grenada, St. Vincent and the Grenadines also joining. Other Eastern Caribbean countries are considering joining, as well as the French and Netherlands Caribbean territories. The signatory countries have all pledged to conserve 20% of their marine and coastal habitats by 2020 because they contain enormous biodiversity with 65 coral and 1 400 fish species, 6 of the 7 species of endangered sea turtles, and more than 300 endemic birds and mammals within an area containing 21,000 km<sup>2</sup> of coral reefs. Moreover, much of the Caribbean economy depends on the Challenge region, with 10 million people and 50% of the Caribbean national incomes based on 'nature' tourism. However, this tourism paradise is now threatened by over-fishing, invasive species, and unsustainable development on the land, with the countries having insufficient funding to protect these resources. This was the catalyst for the Challenge, which is designed as a \$70 million project to be implemented over the next 6 years, with each country proposing Challenge activities, such as:

- developing effectively managed protected areas by hiring, equipping and training park managers and associated staff;
- creating new protected areas during the next 6 years, that will ensure the effective management of a minimum of 2 million hectares of new and existing protected areas;
- decreasing unsustainable fishing practices;
- finding protection strategies to reduce the impacts of global climate change on the area;
- developing and capitalizing protected area trust funds, and seeking other funds such as tourist user fees; and
- creating demonstration sites which will serve to showcase best practice.

The major difficulty, however, for a large, multi-country project is finding reliable, long-term funding. These Caribbean island nations are asking the world community to assist with funds to establish many more MPAs and strengthen the management of existing parks. For example, new funds will promote sustainable tourism, such as whale watching, in the Parque Nacional del Este and Samana Bay in the Dominican Republic, as well as assisting in the protection of coral reef resources. A key component will be the creation of more than US\$45 million national-level protected area Trust Funds to fund rangers, patrol boats, scientific expertise and education programs. The Nature Conservancy has pledged US\$20 million and the German Government has pledged approximately US\$8.6 million. These funds will be used to match upwards of US\$18 million in Global Environment Facility national and sub-regional projects to implement the Challenge. These Caribbean countries lack the capacity and economic base to tackle programs to ensure the long-term sustainable use of their natural resources without this Challenge and the promised funds. Plans should also include a monitoring program to assess progress in conserving the coral reefs and in raising awareness.

## 20. STATUS OF CORAL REEFS AND ASSOCIATED ECOSYSTEMS IN SOUTHERN TROPICAL AMERICA: BRAZIL, COLOMBIA, COSTA RICA, PANAMÁ AND VENEZUELA

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### SUMMARY

- Algae are the most abundant reef organisms in most of the countries; high coral cover occurs at numerous reef locations at the Caribbean (~70%) and Pacific (~95%) coasts;
- No major changes in live coral cover have been observed recently in the region; some localised decline and recovery trends are evident for each country;
- Coral reefs in the region experience many natural and human threats, and predictions suggest that nearly 50% of reefs are at very low risk of decline in 5-10 years, even considering global climate change, and around 40% of reefs could be under high risk of decline in the mid-long term (>10 years);
- Massive coral bleaching occurred in Southern Tropical America during 2005, but the severity varied across the region;
- Reef monitoring has increased, but there is low funding for monitoring programs in all countries; socioeconomic monitoring is restricted to Brazil;
- Information on reef fisheries from monitoring programs is scarce, however, the consensus is for depletion of coral reefs resources, particularly in the Caribbean;
- Seagrass and mangrove communities are mainly threatened by coastal development, sedimentation, pollution, and deforestation.

## INTRODUCTION

The coastal environments in Southern Tropical America are characterized by strong land influences with numerous large rivers, including the Amazon, Orinoco and Magdalena, introducing large amounts of sediments that inhibit the development of extensive coral reefs. Rainfall is among the highest in the world, therefore water turbidity and sedimentation are high. Furthermore, there are several major upwellings (Perú, Gulf of Panamá, Gulf of Papagayo, eastern Colombian Caribbean, and eastern Venezuela) that also reduce reef growth. The best coral reefs are on the Caribbean coasts of Panamá and associated with islands off Colombia and Venezuela. Coral formations are comparatively smaller on the Pacific side, and occur principally along the Costa Rica-Panamá coast.

**Brazil:** Coral reefs occur along 2500 km of the coast on the mostly narrow East Brazil Shelf. This straight coastline is not affected by major rivers and coral reefs grow mostly parallel to the coast, including fringing as well as long bank reefs. The continental shelf widens in the south at Abrolhos Bank where there are the most southern reefs of the Atlantic. The Fernando de Noronha chain rises from the ocean floor to form the only atoll in the South Atlantic Ocean. Coral species diversity is low overall with only 18 species of hard corals, but 8 of these are endemic to Brazil. There are 6 major reef areas: North-eastern Brazil region with 1) Fernando de Noronha chain of oceanic banks, islands and Atol das Rocas, 2) Touros-Natal in the north-east with an extensive line of coastal knoll and patch reefs, and 3) Pirangi-Maceió in the north-east with more developed linear coastal reefs with more species; and Eastern Brazil with 4) Todos os Santos and Camamu Bays including the Tinharé and Boipeba islands, 5) Cabrália/



Porto-Seguro and 6) Itacolomis and Abrolhos. These last three have long fringing and bank reefs formed by mushroom-shaped pinnacles ('chapeirões') and have the highest coral species diversity.

**Colombia:** This is the only South American country with Caribbean (1700 km) and Pacific (1300 km) coastlines with coral reefs. There are about 2700 km<sup>2</sup> of coral reefs in the Caribbean, sparsely distributed among 26 discrete areas: 1) the mainland coast with fringing reefs on rocky shores (Santa Marta and Urabá areas); 2) continental shelf reefs around offshore islands (Rosario and San Bernardo archipelagos); and 3) the oceanic reef complexes of the San Andrés Archipelago in the Western Caribbean. These complexes have the best-developed coral formations and include atolls, bank, barrier, fringing and patch reefs, and contain more than 75% of Colombian coral reefs. Reefs on the Pacific coast are very poor, with Gorgona Island having the only large coral formations. There are a few reef patches in Ensenada de Utría and the oceanic Isla de Malpelo, 350 km off the coast, with coral growing to 35 m depth. Around 60 hard coral species are known from the Caribbean, and 18 from the Pacific.

**Costa Rica:** There are about 100 km<sup>2</sup> of coral reefs on the Caribbean and Pacific coasts. The 212 km long Caribbean coast consists mainly of high energy sandy beaches, with corals growing only in the southeast as fringing reefs growing on fossil carbonate outcrops: 1) Moín-Limón, which is being damaged by the largest port; 2) Cahuita National Park, which includes the largest and best studied fringing reef on the Caribbean coast; and 3) Puerto Viejo-Punta Mona, which has several reef formations. Pacific reefs are more abundant and distributed along the 1254 km coast, although they have low coral diversity and are relatively small in area covered. The principal Pacific reefs are near Santa Elena, Bahía Culebra, Parque Nacional Marino Ballena, Isla del Caño and Golfo Dulce, and also at the oceanic Isla del Coco 500 km offshore.

**Panamá:** The 2987 km coastline in the Caribbean and Pacific has approximately 290 km<sup>2</sup> of reefs, with 99% being in the Caribbean containing more than 70 hard coral species, whereas there are 25 species on the Pacific side. Caribbean coral reefs occur along almost all the coast in 3 major areas: 1) the western coast (Bocas del Toro-Rio Chagres), with the highest coral cover of the Caribbean side; 2) the central coast (Colón-Isla Grande), near the major industrial area and the most degraded Caribbean reefs (less than 4% coral cover); and 3) the eastern coast (San Blas or Kuna-Yala territory), with the most extensive and diverse reefs in Panamá. Most Pacific reefs occur on islands near the coast: 4) the Gulf of Chiriquí, the best fringing reefs in the eastern Pacific; and 4) the Gulf of Panamá, including reefs on Las Perlas archipelago, Taboga and Isla Iguana.

**Venezuela:** Reefs occur mainly in 3 Caribbean areas on the 2875 km Caribbean and Atlantic coastline: 1) the Morrocoy National Park and adjacent reefs (San Esteban, Turiamo and Ocumare de la Costa), with the best developed coral reefs on the coast (more than 30 coral species and reef growth to 20 m depth); 2) the Mochima National Park and adjacent reefs (Coche and Cubagua islands), with more than 20 coral species growing to 14 m; and 3) the oceanic islands, more than 100 km offshore, with the best reefs of Venezuela at Los Roques Archipelago (57 coral species, reef growth to more than 50 m), and also at Las Aves Archipelago, and Isla de Aves, Orchila and Blanquilla islands.

## STATUS OF THE CORAL REEFS 2008

Monitoring data indicate that algae are the dominant organisms in most areas, nevertheless, high coral cover occurs on many reefs in the Caribbean and Pacific. Live coral cover on Caribbean-Atlantic reefs ranged 1–70% while algal cover ranged 4–80%. Pacific reefs had coral cover 0–95% and algal cover 13–86%. Despite trends of decline and recovery at the local scale for each country, reefs in this region have not undergone noticeable changes since 2004.

| Region                        | Reef areas | Coral cover | Algal cover | Trend (s)  |
|-------------------------------|------------|-------------|-------------|------------|
| Atlantic North-eastern Brazil | 3          | 1–29%       | 4–55%       | LN, LD, LR |
| Atlantic Eastern Brazil       | 3          | 2–16%       | 7–62%       | LN, LD     |
| Caribbean Colombia            | 7          | 2–70%       | 23–80%      | LN, LR, LD |
| Caribbean Costa Rica          | 3          | 8–26%       | 62–75%      | LN, LR     |
| Caribbean Panamá              | 11         | 15–29%      | 13–57%      | GN, LD, LR |
| Caribbean Venezuela           | 2          | 3–51%       | 24–44%      | GN, LR     |
| Pacific Colombia              | 3          | 5–95%       | 13–60%      | LD, LR     |
| Pacific Costa Rica            | 4          | 0–37%       | 31–86%      | LR, LD     |
| Pacific Panamá                | 14         | 24–40%      | 37–57%      | GN, LD, LR |

*This table summarises live coral cover and algal cover, and trends observed during 2003-2008 by monitoring programs of the STA-GCRMN Regional Node at all sites. GN=General No Change; GD=General Decline; GR=General Recovery; LN=Localised No change; LD= Localised Decline; LR=Localised Recovery.*

**Brazil:** The medium-scale Brazilian national coral reef monitoring program using Reef Check compatible methodology monitored 8 localities between 2003–2008, 5 in Northeastern Brazil: Atol das Rocas, Fernando de Noronha island, Maracajaú, Tamandaré and Maragogi), and 3 in Eastern Brazil (Itaparica, Porto Seguro and Abrolhos). AGRRA detailed monitoring has been conducted at 5 Eastern Brazil reefs since 1999 (Todos os Santos Bay, Tinharé/Boipeba, Cabralia, Itacolomis and Abrolhos). In 2006, 28 new sites were added at Itacolomis and Abrolhos reefs using Marine Managed Areas Science protocols. Reef Check monitored sites show that nearshore, shallow reefs, less than 1 km from the coast, are in poor condition with less than 5% mean coral cover because of chronic land based stresses. Reefs further than 5 km from the coast, or deeper than 6 m, showed an increase in algal cover but also some local coral recovery, especially *Millepora* species. Increased protection has probably also contributed. Mild coral bleaching was observed in 2003 and 2005 along the 2000 km coast. All trophic levels of fish were significantly more abundant on fully protected, no fishing areas, than areas in general use or without enforcement.

Monitoring via the AGRRA methodology shows that reefs less than 5 km from the coast are in poor condition with a mean of less than 4% coral cover, and more than 40% cover of macroalgae (similar to cover in 2003). Reefs more than 5 km offshore and in Marine Protected Areas have more than 10% coral cover and less than 10% algal cover. Damage from sewage pollution, increased sedimentation and low water turbidity, as well as damage by tourists and over-exploitation can explain the condition. Coral cover has declined since 2003 at Itacolomis

and the Abrolhos area, from a maximum of 21% prior to 2003, to a maximum of 16% recently. The Abrolhos reefs are more remote from human pressures but have a higher incidence of coral diseases which have particularly affected the Brazilian-endemic coral, *Mussismilia braziliensis*.

**Colombia:** Pacific coral reefs are in better condition than those in the Caribbean, but there are wide variations in coral cover. Caribbean mean coral cover ranged from 5% (Banco de las Ánimas and Guajirata) to 40% (Urabá) and algal cover from 30.9% (Rosario Islands) to 51.2% (Santa Marta). In the Pacific coral cover average was 55% at Gorgona Island, and the highest algal cover was at 43% Malpelo Island. More data are in the Table below. The prevalence of coral diseases was low (<4.2%) in Caribbean reefs with White plague and Dark spots diseases predominating. There has been little recovery of reef organisms (long-spined sea urchin, *Diadema antillarum* and the Caribbean sea fan, *Gorgonia ventalina*) that suffered mass mortality several decades ago. Sea urchin density is higher in the Pacific, as high as 80 individuals per 20m<sup>2</sup> on Gorgona Island. Coral cover in the Caribbean was essentially stable with only the Tayrona area showing a significant decrease. Some other reefs showed significant declines in coral species such as *Siderastrea siderea* and *Acropora palmata* on shallow reefs, and *Montastraea cavernosa* on deep reefs, but overall cover remained largely unchanged. In the Pacific Gorgona Island showed a significant decline in coral cover since 2004 but not at all depths. The major reductions in coral cover often coincided with extreme low tides exposing the corals. Some changes are evident at different depths of species, suggesting differential responses of corals to stresses. For instance, the 2005 bleaching event was the most severe for the Colombian Caribbean in the last 25 years, but the severity of bleaching varied between areas: Rosario and San Bernardo suffered severe bleaching; San Andrés and Providencia were moderately affected; and Santa Marta experienced minimal bleaching.

**Costa Rica:** Gandoca-Manzanillo National Wildlife Refuge on the Caribbean side now has high live coral cover, high densities of *Diadema antillarum* (> 0.6/m<sup>2</sup>) and low macro-algal cover. This indicates that corals have increased in abundance, possibly due to the recovery of sea urchins. In Cahuita National Park, at Meager Shoal, a 2% coral cover increase (from 15 to 17%) occurred between 2000 and 2004, with a decrease in coralline algal cover (17 to 5%). Coral colony diseases, injuries and bleaching have decreased from 24% in 2000 to 10% in 2004, but the park continues to be damaged by sediments with no significant recovery since the late 1970s. On the Pacific side, the invasive macro-alga, *Caulerpa sertularoides*, overgrows *Pollicopora* reefs killing the coral or reducing growth and resulting in flow-on disturbance effects. Algal densities were highest adjacent to areas with high concentrations of nutrients in the upwelling season, as well as near land runoff with heavy sedimentation. Recurrent red tides have killed more than 80% of the coral *Pavona clavus* at Viradores Reef with very low recent recovery. In Parque Nacional Marino Ballena small increases in coral cover from 5.9% to 7.8% were reported at Punta Uvita and at Las Tres Hermanas from 36.5% to 39.5% between 2003 and 2005, but decreases occurred in 2006 (4.9% and 34.3% respectively). Suspended sediments and nutrients are affecting the corals in the park, with sedimentation rates ranging from moderate (44 mg cm<sup>-2</sup> day<sup>-1</sup>) to heavy (117 mg cm<sup>-2</sup> day<sup>-1</sup>). These nutrients and sedimentation come from on-going land erosion enhanced by heavy rains. At Isla del Caño Biological Reserve coral cover in March 2007 was between 19.7 to 34.8% (mean 26.6±5.6 %), whereas at Isla del Coco, the coral cover was between 10% and 50% with most placed between 10 and 35%.

**Panamá:** Reefs along the Caribbean coast had mean coral cover of 20.1% ( $\pm 1.7$  SE;  $n = 11$ ); lower than those on the Pacific coast, 35.1% ( $\pm 7.7$ ;  $n = 14$ ). Coral cover has changed little from 1999 to 2007 for both coasts. Similarly, coral cover for all Panamá sites was 30.6% ( $\pm 5.6$ ); effectively stable over the last 9 years. Macroalgal (frondose and filamentous) cover increased significantly from 1999 to 2005 and declined in 2007 on Caribbean reefs (41.2%  $\pm 5.5$ ) while the cover on Pacific reefs declined from 57% ( $\pm 11.8$ ) in 2003 to 52.8% ( $\pm 8.8$ ) in 2007. Overall, there was no significant change from 2000 to 2008. Crustose coralline algae (CCA), a potential indicator of health, showed a slight but non-significant decrease in Caribbean reefs for the time period (1.9%  $\pm 1.0$  for 2007) while Pacific reefs showed a slight increase (6.8%  $\pm 3.2$ ) with no trend during the 9 years for Panamá (5.3%  $\pm 2.3$ ). Reefs with high cover of crustose coralline algae are a better habitat for new coral recruits and indicate a relative healthy environment. Reefs with high algal cover have been damaged by natural or human disturbances or may be under stress. This baseline dataset combines reefs under different initial conditions which allows assessment of long-term changes in response to natural or human disturbances. The initial idea was not to establish sites on the best reefs (pristine) but at different localities encompassing a gradient of degradation and habitats representative of the country.

**Venezuela:** The general condition of monitored reefs remained unchanged between 2003 and 2008, particularly coral and algal cover. However, coral diseases have increased drastically: in 2003 diseases were present at only 2 sites at 1.5% prevalence of infected colonies, currently diseases are present at all reef sites at 26% prevalence. The only example of localized recovery was Playa Caimán where there are no coral diseases and very low hard coral cover: cover of corals and sponges increased from 1.4 to 4.3% and 0.1 to 1.9% between 2003 and 2006. Caribbean Yellow band disease was the most prevalent coral disease (up to 22% on Cayo Norte) followed by infections by the ciliate, *Halofolliculina* sp. (up to 12%), and White syndrome (up to 5%). Most colonies affected by diseases (>95%) were the slow growing, massive reef framework building corals which may threaten the long-term recovery. Coral fish density (up to 135 individuals per 100 m<sup>2</sup>) were directly correlated with coral cover. However, on 2 reef sites with similar fish densities and high coral cover, the fish biomass on Los Roques was twice that on Morrocoy due to different species composition with large numbers of parrotfish and smaller predators influencing the biomass respectively. These are national parks and fishing is lower at Los Roques due to a small human population and stronger regulations. The 2005 bleaching only caused mild damage to these reefs compared with other Caribbean reefs, however, the potential impact of global climate change, diseases and over-fishing increase concern for the future. Oil exploitation offshore has added another potential threat for Venezuelan reefs.

## CURRENT THREATS TO CORAL REEF BIODIVERSITY

Many natural and human threats occur throughout Southern Tropical America; the most significant threats are: over-fishing, sedimentation/siltation, tourism activities, deforestation and urban development. Among the most important 'natural' threats are algae proliferation, coral bleaching, global warming and ENSO events (although these are all linked to human activities). The high stress reefs are on the Caribbean coast of Panamá, and Pacific coast of Costa Rica. The least threatened reefs are in the Colombian Pacific. However, the future predictions for reefs in the region are relatively comforting: about 50% of reefs were considered as 'No Threatened Reefs' in the short term (5–10 years), while less than 35% were categorized as 'Critical Reefs'; and 40% of reefs could be threatened in the mid-term (>10 years).

| Threats  | AEB       | ANB       | CCO       | CCR       | CPA       | CVE       | PCO       | PCR       | PPA       | Global score |
|--|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|--------------|
| <b>A. 'Natural'</b>                                |           |           |           |           |           |           |           |           |           |              |
| 1. Algal proliferation                             | 5         | 5         | 3         | 5         | 4         | 4         | 1         | 5         | 3         | 35           |
| 2. Coral bleaching                                 | 2         | 1         | 5         | 3         | 3         | 4         | 4         | 5         | 5         | 32           |
| 3. Global warming                                  | 2         | 2         | 3         | 5         | 4         | 5         | 3         | 5         | 3         | 32           |
| 4. ENSO events                                     | 2         | 2         | 1         | 3         | 3         | 0         | 4         | 5         | 5         | 25           |
| 5. Phytoplankton blooms/red tides                  | 2         | 2         | 1         | 0         | 3         | 3         | 1         | 5         | 5         | 22           |
| 6. Coral disease outbreaks                         | 2         | 1         | 3         | 1         | 2         | 5         | 1         | 0         | 1         | 16           |
| 7. Low tide exposure                               | 5         | 0         | 0         | 0         | 2         | 0         | 4         | 2         | 2         | 15           |
| 8. Earthquakes/landslides                          | 0         | 0         | 0         | 5         | 2         | 0         | 2         | 3         | 2         | 14           |
| 9. <i>Diadema</i> mortality                        | 0         | 0         | 3         | 5         | 4         | 1         | 0         | 0         | 0         | 13           |
| 10. Upwelling                                      | 0         | 0         | 1         | 0         | 2         | 2         | 2         | 2         | 4         | 13           |
| 11. Carbonate ion decrease to reduce calcification | 2         | ?         | ?         | 0         | 2         | 1         | ?         | 4         | 1         | 10           |
| 12. Hurricanes/storms                              | 0         | 1         | 4         | 0         | 1         | 0         | 0         | 0         | 0         | 6            |
| 13. <i>Acanthaster</i> proliferation               | 0         | 0         | 0         | 0         | 0         | 0         | 1         | 1         | 1         | 3            |
| <b>NATURAL IMPACT RATINGS</b>                      | <b>22</b> | <b>14</b> | <b>24</b> | <b>27</b> | <b>32</b> | <b>25</b> | <b>23</b> | <b>37</b> | <b>32</b> |              |
| <b>B. Anthropogenic</b>                            |           |           |           |           |           |           |           |           |           |              |
| 1. Over-fishing                                    | 4         | 4         | 5         | 5         | 5         | 4         | 2         | 5         | 4         | 38           |
| 2. Increased sedimentation/siltation               | 5         | 5         | 4         | 5         | 4         | 4         | 2         | 5         | 3         | 37           |
| 3. Tourism activities                              | 4         | 3         | 4         | 5         | 5         | 4         | 2         | 5         | 5         | 37           |
| 4. Deforestation                                   | 5         | 5         | 3         | 5         | 4         | 4         | 2         | 5         | 3         | 36           |
| 5. Urban development                               | 5         | 4         | 4         | 4         | 5         | 4         | 0         | 5         | 5         | 36           |
| 6. Fish extraction                                 | 3         | 4         | 5         | 3         | 4         | 3         | 2         | 5         | 4         | 33           |
| 7. Sewage pollution                                | 4         | 4         | 4         | 4         | 4         | 2         | 0         | 5         | 3         | 30           |
| 8. Garbage pollution                               | 4         | 5         | 3         | 3         | 4         | 2         | 1         | 3         | 5         | 30           |
| 9. Changes to river beds                           | 1         | 4         | 3         | 3         | 4         | 4         | 1         | 4         | 2         | 26           |
| 10. Oil pollution                                  | 2         | 4         | 2         | 3         | 4         | 4         | 2         | 2         | 2         | 25           |
| 11. Dredging                                       | 2         | 2         | 2         | 4         | 3         | 3         | 0         | 4         | 3         | 23           |
| 12. Diving activities                              | 2         | 2         | 2         | 3         | 3         | 1         | 2         | 4         | 3         | 22           |
| 13. Nautical activities                            | 2         | 2         | 2         | 1         | 2         | 3         | 2         | 4         | 2         | 20           |
| 14. Coral extraction for curio trade               | 3         | 4         | 2         | 0         | 3         | 1         | 2         | 2         | 2         | 19           |
| 15. Heavy metal pollution                          | 3         | 3         | 1         | 1         | 4         | 2         | 0         | 1         | 3         | 18           |
| 16. Industrial development                         | 3         | 3         | 2         | 0         | 3         | 2         | 0         | 0         | 2         | 15           |
| 17. Dynamite fishing                               | 2         | 4         | 4         | 0         | 0         | 0         | 0         | 0         | 2         | 12           |
| 18. Coral mining for construction                  | 2         | 2         | 2         | 0         | 4         | 0         | 0         | 0         | 1         | 11           |
| <b>ANTHROPOGENIC IMPACT RATINGS</b>                | <b>56</b> | <b>64</b> | <b>54</b> | <b>49</b> | <b>65</b> | <b>47</b> | <b>20</b> | <b>59</b> | <b>54</b> |              |
| <b>TOTAL IMPACT RATINGS</b>                        | <b>76</b> | <b>78</b> | <b>78</b> | <b>76</b> | <b>97</b> | <b>72</b> | <b>43</b> | <b>96</b> | <b>86</b> |              |

*This lists the potential severity of natural and anthropogenic threats to coral reef biodiversity in Southern Tropical America within 2000–2008 as assembled by regional coral reef experts. A score of 5 indicates a very high risk of reef damage. AEB: Atlantic Eastern Brazil, ANB: Atlantic North-eastern Brazil, CCO: Caribbean Colombia, CCR: Caribbean Costa Rica, CPA: Caribbean Panamá, CVE: Caribbean Venezuela, PCO: Pacific Colombia, PCR: Pacific Costa Rica, PPA: Pacific Panamá. National experts rated threats to coral reef degradation as: 0=no threat; 1=low threat; 2=localised low threat; 3=average threat; 4=localised major threat; 5=general major threat.*

| Region                       | No Threatened Reefs (%) |    | Critical Reefs (%) |    | Threatened Reefs (%) |    |
|------------------------------|-------------------------|----|--------------------|----|----------------------|----|
|                              | GC + HP                 | HP | GC + HP            | HP | GC + HP              | HP |
| Atlantic Northeastern Brazil | 30                      | 30 | 25                 | 20 | 30                   | 60 |
| Atlantic Eastern Brazil      | 40                      | 30 | 10                 | 8  | 50                   | 40 |
| Caribbean Colombia           | 50                      | 40 | 25                 | 20 | 60                   | 30 |
| Caribbean Costa Rica         | 40                      | 5  | 60                 | 50 | 30                   | 20 |
| Caribbean Panamá             | 45                      | 20 | 30                 | 60 | 25                   | 20 |
| Caribbean Venezuela          | 50                      | 40 | 30                 | 20 | 60                   | 30 |
| Pacific Colombia             | 70                      | 95 | 10                 | 5  | 30                   | 15 |
| Pacific Costa Rica           | 30                      | 20 | 70                 | 60 | 40                   | 30 |
| Pacific Panamá               | 55                      | 60 | 25                 | 25 | 20                   | 15 |

*Regional experts assembled these predictions for coral reefs within Southern Tropical America Node under two scenarios: GC+HP = global change + human pressures; HP = only human pressures. These predictions are a cause for optimism about the future of these reefs. No Threatened Reefs: proportion of reefs at very low risk of decline in the short term (5–10 years). Critical Reefs= proportion of reefs under high risk of decline in the short term. Threatened Reefs= proportion of potential reefs under high risk of decline in the mid-long term (>10 years).*

### THE BRAZILIAN NATIONAL CORAL REEF MONITORING PROGRAM

The Brazilian National Coral Reef Monitoring Program started in 2002, and includes all major reef areas in Brazil. Surveys were conducted in 90 sites inside 12 reefs. Monitoring is conducted in 8 localities in those areas, including reefs inside protected areas with full protection (4) and sustainable use (4). Trained scientists and university students, as well as park managers, NGO personnel and dive volunteers were part of the teams. Data gathering is more detailed, but still compatible with the Reef Check protocols. New indicators were added to the standard Reef Check categories and fish, invertebrates and corals were recorded to the species level. These detailed data included results on coral and fish diversity, latitudinal differences in species abundances and detecting effects of different management strategies along 2000 km of the coast. The program is funded by the Ministry of Environment and Instituto Recifes Costeiros and coordinated by the Federal University of Pernambuco. Institutions supporting the monitoring/survey efforts: Atol das Rocas-ICMBIO; Noronha-ICMBIO and Atlantis Divers; Maracajau-IDEMA, UFRN and Maracajau Divers; Tamandaré and Maragogi- CEPENE/ICMBIO and Recifes Costeiros Project; Itaparica-PROMAR; Porto Seguro-Coral Vivo Project; Abrolhos-ICMBIO and Aratur Divers. Efforts were aligned with the Campaign for Conscious Conduct at Reef Environments of the Ministry of Environment (from Ana Lidia Bertoldi Gaspar, reefcheckbrasil@yahoo.com.br, Project Manager, Instituto Recifes Costeiros).

## CURRENT MONITORING CAPACITY

Reef monitoring has been conducted in the region for more than 20 years and new programs have recently been established (SeaScape and MMAS). However the expansion of monitoring and the number of reefs monitored has been very slow since 2000. All countries in the region have strong professional capacity and generally good logistics for monitoring, but the principal restriction is a lack of consistent funding. Although ecological monitoring information is gathered by all countries, socioeconomic monitoring only occurs in Brazil.

| Country Attributes                          | Costa Rica  | Panamá                                    | Colombia                                  | Venezuela           | Eastern Brazil          | North-East Brazil                     |
|---|---|---|---|---------------------|-------------------------|---------------------------------------|
| Marine research institutions                | 2   | 1   | 7   | 6                   | 15                      |                                       |
| Active coral reef researchers               | 8   | 6   | 28  | 6                   | 30                      |                                       |
| Reef monitoring programs                    | CARICOMP, CIMAR, Reef Check, Eastern Pacific SeaScape | CARICOMP, PCRMN, Eastern Pacific SeaScape | CARICOMP, SIMAC, Eastern Pacific SeaScape | CARICOMP, STA-GCRMN | AGRRA, Reef Check, MMAS |                                       |
| Monitored reef localities                   | 6   | 33  | 9   | 2                   | 5                       | 8                                     |
| Reef monitoring stations                    | 13  | 33  | 36  | 5                   | 58                      | 48                                    |
| Years of reef monitoring                    | 15  | 22  | 16  | 15                  | 9                       | 5                                     |
| Monitored parameters                        | 16  | 8   | 15  | 13                  | 14                      | 38 + 13 (biophysical / socioeconomic) |
| 2003–2008 reef monitoring investment (US\$) | 90 000  | 182 000                                   | 180 000                                   | 25 000              | 50 000                  | 155 184                               |
| Funding capacity for monitoring             | Low   | Low                                       | Low                                       | Low                 | Low                     | Low                                   |
| Professional capacity for monitoring        | High  | High                                      | High                                      | High                | High                    | High                                  |
| Logistic capacity for monitoring            | Medium  | High                                      | High                                      | Medium              | High                    | Medium                                |
| Socioeconomic monitoring                    | None  | None                                      | Scarce                                    | None                | Medium                  | Medium                                |

*This table shows the current reef monitoring capacity and activity in the countries of Southern Tropical America.*

## STATUS OF MANGROVES, SEAGRASSES AND FISHERIES: 2008

**Brazil:** Mangrove forests occur along the coast of Brazil in the lower segments of rivers; the north coast has more than 50% of all mangrove areas, especially in the states of Pará and Maranhão. The Pará mangroves are in the transition zone of the Amazon River and are well developed and very tall, reaching 45 m. Maranhão mangroves occupy both sides of São

Marcos Bay and are the most extensive and structurally complex in Brazil. These forests are largely intact because of low population density and poor accessibility. The north-eastern and eastern coast mangroves occur near dense populations (São Francisco River, Todos os Santos and Camamu Bays and Caravelas strandplain). *Rhizophora mangle* dominates but *Avicennia* and *Laguncularia racemosa* are common. Seagrasses occur in coastal areas with *Halodule wrightii* dominant. Seagrass beds are important nursery areas for reef fishes but are under threat, including sedimentation. Mangroves in Brazil come under the Ramsar convention, but are still heavily threatened by over-exploitation for timber, firewood and charcoal, and bark for tannin used to dye ship sails. They are also threatened by urban expansion, discharge of untreated sewage, industrial pollution and agricultural pesticides. Large areas were converted to rice cultivation or aquaculture, especially shrimp farming, leading to increased sediment flows to the adjacent coral reefs. In April 2008, the Minister of Environment signed an act banning the development of shrimp farms in all federal protected areas, which should improve protection for those ecosystems. Brazil has approved a GEF project 'Effective Conservation and Sustainable Use of Mangrove Ecosystems in Brazil', in association with NGOs to implement mangrove protected areas to safeguard fisheries resources. Over-fishing is threatening coral reefs and associated ecosystems, especially on the densely populated north-eastern coast where many small and medium scale fisheries operate on coral reefs. Indicator fish populations correlate directly with the level of fishing pressure, with fishing now moving down the food chain from the large predators (groupers, snappers and sharks) to trap fishing for national and international markets. The traps take herbivorous fishes (parrotfish and surgeonfish) and virtually all other reef fish groups as bycatch. Few attempts have been made to manage coral reef fisheries resources in Brazil, other than establishing protected areas.

**Colombia:** Colombia is tenth in the world for mangrove resources, with around 319 714 ha (Pacific coast has 233 404 ha or 73%; Atlantic coast has 86 310 ha), or almost 1% of the forest surface area of Colombia. There are 10 species in Colombia (*Rhizophora mangle*, *R. harrisonii*, *R. racemosa*, *R. samoensis*, *Laguncularia racemosa*, *Conocarpus erectus*, *Avicennia germinans*, *A. tonduzii*, *Pelliciera rhizophorae*, *Mora oleifera*) growing on the Pacific coast but only 6 are found on the Caribbean coast (*R. mangle*, *R. harrisonii*, *L. racemosa*, *C. erectus*, *A. germinans*, *P. rhizophorae*). In dry very saline regions the black mangrove (*Avicennia germinans*) is dominant on the Caribbean coast (Alta Guajira), whereas the red mangrove (*Rhizophora* sp.) prevails in more continental waters. *Rhizophora* spp. dominate on the Pacific Coast. Colombia has 6 seagrass species, *Thalassia testudinum*, *Halodule wrightii*, *Syringodium filiforme*, *Halophila decipiens*, *H. baillonis* and *Ruppia maritima*, with a total cover in the Colombian Caribbean of more than 43 223 ha (or 0.12 % of the Colombian shelf). Only 2150 ha (5 %) are around the oceanic Archipelago of San Andrés and Providencia, 700 km off the Colombian coast; the remaining area is in nearshore waters and around nearby offshore islands. The Guajira Peninsula has more than 82% of the seagrasses. Seagrass distribution is not continuous along the continental coast, probably because of low salinity, high turbidity, high wave energy in shallow waters and different human uses of the coasts. The seagrass and mangrove communities are mainly threatened by human activities: habitat degradation, especially from boats, coastal development, illegal extraction, declining water quality, sedimentation, high salinity and deforestation (for mangroves). The slime fungus disease *Labyrinthula* sp. has been identified on *Thalassia* leaves in the Tayrona National Natural Park. Commercial species such as snappers, groupers and lobsters are scarce in the Caribbean, whereas fish densities are higher (10–21/60m<sup>2</sup>) for groupers and snappers on Pacific reefs (especially Malpelo Island).

**Costa Rica:** The Caribbean coast has extensive seagrass beds but only 2 small mangrove forests. The main seagrass species are *Thalassia testudinum* and *Syringodium filiforme* while the main mangrove is *Rhizophora mangle*. The seagrass bed at Parque Nacional Cahuita and the mangrove forest at the Refugio Nacional de Vida Silvestre Gandoca-Manzanillo are being monitored via CARICOMP. Both are within protected areas thus the main threats are external: high sediment loads, pollution, and climate change. There are few small seagrass patches, mainly *Ruppia maritima*, on the Pacific, but extensive mangrove forests consisting mainly of *Rhizophora mangle* and *Avicennia* spp. The largest seagrass patches in Bahía Culebra were obliterated by a strong storm in the mid 1990s. The existing patches are threatened by habitat alteration. Mangrove forests are threatened by habitat degradation, illegal cutting, pollution, excessive sedimentation, reduction of water supply, and human encroachment. Similar to other parts of the world, fish stocks in Costa Rica are over-exploited. There are efforts in some Marine Protected Areas to stop fishing, legal (i.e. artisanal) and illegal, and there are some private initiatives to develop responsible fishing practices; but there are few government efforts. A major problem is that the governing board of the National Institute of Fisheries and Aquaculture is controlled by fishers. Until that changes, there is little chance of implementing sustainable uses of marine resources.

**Venezuela:** Mangroves are well distributed on the Venezuelan coast, except on the central coast, occupying 250 000 ha, especially in the deltas of the large rivers (San Juan, Neverí, Unare, Tuy, Aroa, Yaracuy, Tocuyo and Catatumbo) but most of the mangroves (73%) are in the Orinoco. Mangroves also occur around the large islands of Margarita and the archipelagos. Although protected by law, the 6 species reported are being affected by coastal development (logging and habitat destruction). Seagrass beds are less extensive than mangroves but still very ubiquitous, with the main beds where reefs and mangroves also occur. Most marine species are over-exploited, especially lobsters, groupers and queen conchs. For example, conch extraction was totally banned in 1991 but populations have not recovered, probably because of furtive harvesting. Lobster fishing is also banned from May to October, but sizes and the effort required suggest over-exploitation. Various edible gastropods have been replaced as each species becomes scarce in localities such as Morrocoy. The main problem for conservation of mangroves and seagrasses seems to be insufficient enforcement of regulations and over-exploitation of target species.

## CONCLUSIONS:

It is difficult to generalise on the status of coral reefs in the STA region because the cover of algae and corals varies considerably at different spatial scales. Algae were the most abundant organisms for most areas, however, high coral cover can be found at numerous reef locations at the Caribbean (up to 70% cover) and Pacific (up to 95% cover). Despite trends in decline and recovery at local scales in each country, the reefs have been suffering from the same recent threats: mass coral bleaching, over-fishing, sedimentation/siltation, tourism activities, deforestation and urban development. Fortunately, the reefs have not undergone noticeable recent changes. Although reef monitoring has been conducted for more than 20 years, the number of sites is still very low and funding limitations mean that maintaining current programs is difficult. While traditional reef monitoring programs have focused on the structural components, other functional aspects such as the resistance and resilience should be included, especially with increasing climate change. Furthermore, socioeconomic monitoring should

be implemented to assess how human activities are affecting modern reefs. Thus integrated monitoring will assist in finding answers to mitigate reef decline, enhance coral recovery and improve the quality of life for local people. Since seagrasses and mangroves are also threatened by similar factors, similar protection and management strategies should be applied.

#### **RECOMMENDATIONS:**

**Brazil:** Many coral reef protection, management and recovery initiatives have been developed in Brazil, however, much effort is still needed for effective conservation of Brazilian reefs. Few actions have been implemented to manage reef fisheries in Brazil, other than establishing protected areas; only a small area is fully protected and there is inadequate enforcement. Sedimentation and pollution are chronic problems; and a combination of actions of protecting and rehabilitating riparian vegetation, conserving coastal areas, and implementing best practices for land use are necessary. As overseas and national tourism is growing rapidly, it is hoped that conservation will become a major attraction.

**Colombia:** It is important that Colombia continues to develop long term monitoring after 10 years of SIMAC, because this is the most useful tool to detect temporal trends in coral reefs. Only a third of Colombian reefs are being monitored, therefore new areas need to be included to obtain a more complete picture of reef status. In addition, effective conservation and protection measures in the Colombian reefs are required to complement the monitoring. For instance, specific government policies and laws for coral reef sustainable management need to be developed in the next few years, as well as protecting natural parks and reserves through implementing effective management plans and law enforcement.

**Costa Rica:** Monitoring should continue at existing sites and new coral reefs should be included if more funds are available. Some monitoring should be carried out by park rangers (most reefs in Costa Rica are within Protected Areas). Unfortunately, monitoring is not in their job description and has become sporadic and voluntary. At least two people should be hired to dedicate time to monitoring in Protected Areas.

**Panamá:** Coral reefs in Panamá showed no major changes in coral cover when averaged, but there are some exceptions: some reefs showed significant decreases or increases in cover and these warrant further analysis to support management actions. The monitoring program should continue yearly and include new assessments such as fish diversity and biomass. Panamá has baseline data for almost all reefs in the Caribbean and Pacific for resource managers. However, coastal development is almost unstoppable, and is occurring at an accelerating rate along the entire coast. Marine reserves have been expanded recently but nearby developments may affect those areas.

**Venezuela:** The coral reefs require strengthened law enforcement for their protection as most large formations are already in protected areas. Thus, stronger involvement of authorities and education are probably the major needs and challenges for reef conservation. Isolated efforts of installing mooring buoys to avoid damage by boat anchoring have not been successful due to a lack of maintenance. Also, management decisions should be informed by the results from the monitoring of reef conditions.

### DECLINE OF CALCIFICATION RATES OF THE ENDEMIC CORAL *MUSSISMILIA BRAZILIENSIS*: THERMAL STRESS ALERTS IN BRAZIL

Stresses to corals can often be detected in the calcareous skeletons of massive corals. Cores were taken from colonies of *Mussismilia braziliensis*, the major reef-builder in the Abrolhos region. Coral growth as linear extension, density bands and calcification rate were evaluated using computerized tomography techniques. The mean annual linear extension was  $0.8 \pm 0.05$  cm per year; the calcification rate between 1924 and 2003 was  $1.37 \pm 0.23$  g.cm<sup>-2</sup>.y<sup>-1</sup> and between 1979 and 2003 it was  $1.24 \pm 0.17$  g.cm<sup>-2</sup>.y<sup>-1</sup>. Annual climate anomalies over 30 years show that the calcification rate was directly controlled by water temperatures and indicate a strong influence of El Niño events in the Abrolhos reefs. This 10% reduction in coral calcification in the last 25 years indicates that global climate changes are occurring in the South Atlantic Ocean and reducing the amount of calcium carbonate precipitated on the Abrolhos reefs (from Marília Oliveira, mariliad@ufba.br, Federal University of Bahia, with funding support from CNPq, FAPESB, Conservation International-Brazil).

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Departamento de Biología y Centro de Estudios en Ciencias del Mar; Mateo López-Victoria Mateo.Lopez-Victoria@bio.uni-giessen.de, Institut für Allgemeine und Spezielle Zoologie, Justus-Liebig Universität; Juan Armando Sánchez juansanc@uniandes.edu.co, Universidad de los Andes, Departamento de Ciencias Biológicas, Laboratorio de Biología Molecular Marina. **Costa Rica:** Jorge Cortés<sup>1, 2</sup>, Juan José Alvarado<sup>1</sup>, Carlos Jiménez<sup>1</sup>, Ana C. Fonseca, Eva Salas<sup>1</sup>, Jaime Nivia<sup>1</sup>, Cindy Fernández<sup>1</sup> 1) Centro de Investigación en Ciencias del Mar y Limnología (CIMAR), jorge.cortes@ucr.ac.cr, coralescimar@yahoo.com, 2) Escuela de Biología, Universidad de Costa Rica. **Panamá:** Héctor M. Guzmán, Smithsonian Tropical Research Institute, Panamá, guzmanh@si.edu. Venezuela: Carolina Bastidas cbastidas@usb.ve, Sebastián Rodríguez sebastianr@usb.ve, Denise Debrot ddebrot@gmail.com, Aldo Cróquer acroquer@usb.ve, INTECMAR-Universidad Simón Bolívar.

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## APPENDIX I: SPONSORING ORGANISATIONS, CORAL REEF PROGRAMS AND MONITORING NETWORKS

### AFD - AGENCE FRANÇAISE DE DÉVELOPPEMENT

French government agency contributing to the economic and social development of developing countries and the French overseas departments and territories.  
**Contact:** Dominique Rojat, rojatd@afd.fr; www.afd.fr.

### AGRRA – ATLANTIC AND GULF RAPID REEF ASSESSMENT

International collaboration of scientists and managers determining the regional condition of reefs in the Western Atlantic and Gulf of Mexico.  
**Contact:** Robert Ginsburg, info@agrra.org; www.agrra.org

### ARC CENTRE OF EXCELLENCE FOR CORAL REEF STUDIES

Australian research centre undertaking world-best integrated research for sustainable use and management of coral reefs.  
**Contact:** Terry Hughes, info@coralcoe.org.au; www.coralcoe.org.au

### AIMS – AUSTRALIAN INSTITUTE OF MARINE SCIENCE

One of Australia's key research agencies and particularly committed to marine research in the tropics.  
**Contact:** H.sweatman@aims.gov.au; www.aims.gov.au

### CARICOMP – CARIBBEAN COASTAL MARINE PRODUCTIVITY PROGRAM

Caribbean marine laboratories, parks and reserves network monitoring coral reefs, seagrasses and mangroves with standard protocols in undisturbed sites.  
**Contact:** www.mona.uwi.edu/cms/caricomp.htm

### CBD – CONVENTION ON BIOLOGICAL DIVERSITY

UN agency for sustainable use, fair and equitable sharing of benefits, and conservation of biological diversity, including genetic resources.  
**Contact:** secretariat@cbd.int; www.biodiv.org

### CI – CONSERVATION INTERNATIONAL

Global, field-based environmental organisation that promotes the protection of biological diversity.  
**Contact:** www.biodiversityscience.org; www.conservation.org

### CORAL – THE CORAL REEF ALLIANCE

NGO in California dedicated to protecting coral reef health by integrating ecosystem management, sustainable tourism, and community partnerships.  
**Contact:** Brian Huse, info@coral.org; www.coral.org

### CORDIO – COASTAL OCEANS RESEARCH AND DEVELOPMENT IN THE INDIAN OCEAN

Regional, multi-disciplinary research program investigating reef responses to disturbance and improving socioeconomic welfare of user communities in the Indian Ocean. **Contact:** jerker.tamelander@iucn.org

### CRTR – CORAL REEF TARGETED RESEARCH & CAPACITY BUILDING FOR MANAGEMENT PROGRAM

World Bank and GEF funded international and multi-themed coral reef research project to build capacity via 4 centres of excellence to support coral reef management. **Contact:** info@gefcoral.org; www.gefcoral.org

### GCRMN – GLOBAL CORAL REEF MONITORING NETWORK

Formed in 1995 as an operational unit of ICRI, GCRMN seeks to encourage and coordinate community, management and research levels of monitoring.  
**Contact:** clive.wilkinson@rrrc.org.au; www.gcrmn.org

### ICRAN – INTERNATIONAL CORAL REEF ACTION NETWORK

A public/private partnership response to the ICRI's Call to Action in 2000 to conserve and manage coral reefs worldwide.  
**Contact:** Kristian Teleki, kteleki@icran.org; www.icran.org

### ICRI – INTERNATIONAL CORAL REEF INITIATIVE

Partnership among governments, international organizations and non-government organisations to preserve coral reefs and related ecosystems. Co-hosted by Mexico and the United States until June 2009.  
**Contact:** Emily Corcoran, UNEP-WCMC, UK, icri@unep-wcmc.org; www.ICRIForum.org

### IFRECOR – FRENCH CORAL REEFS INITIATIVE

National program for coral reefs in French tropical overseas territories.  
**Contact:** Bernard Salvat, Ecole Pratique des Hautes Etudes, Université de Perpignan, France, bsalvat@univ-perp.fr

### IOC/UNESCO – INTERGOVERNMENTAL OCEANOGRAPHIC COMMISSION

UN focal point for marine science, research and observations to improve knowledge on ocean resources, nature and sustainability for marine management and policy development. **Contact:** Henrik Enevoldsen, h.enevoldsen@unesco.org; www.ioc.unesco.org

### IOI – INTERNATIONAL OCEAN INSTITUTE

Knowledge-based non-government, non-profit international organisation devoted to the sustainable development of the oceans.  
**Contact:** ioihq@ioihq.org.mt; www.ioinst.org

### IUCN – INTERNATIONAL UNION FOR THE CONSERVATION OF NATURE

Partnership of 181 countries and government agencies and NGOs to influence, encourage and assist societies conserve nature and ensure sustainable use of natural resources. **Contact:** Carl Gustaf Lundin, Global Marine Program, IUCN, james.oliver@iucn.org; www.iucn.org

### ISRS – INTERNATIONAL SOCIETY FOR REEF STUDIES

Leading organisation for professional scientists, managers, and students of coral reef studies.  
**Contact:** Richard Aronson, President, raronson@disl.org; www.fit.edu/isrs

### JAPAN – MINISTRY OF THE ENVIRONMENT

Supports Japanese coral reef science, monitoring and management and host of East Asia Seas Regional node of GCRMN. **Contact:** Ministry of the Environment, coral@env.go.jp; www.env.go.jp. International Coral Reef Research and Monitoring Center, okironc@coremoc.go.jp; www.coremoc.go.jp

**NOAA – NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION USA**

US Agency dedicated to researching and predicting weather and climate-related events and protecting the coastal and marine resources of the USA.  
**Contact:** coralreef@noaa.gov; www.coralreef.noaa.gov

**NORWAY – MINISTRIES OF FOREIGN AFFAIRS AND ENVIRONMENT**

Responsible for Norway's Strategy for Environment in Development Cooperation and integration and funding of environment themes in multilateral programs. **Contact:** postmottak@md.dep.no; www.mfa.no

**PROJECT AWARE**

Volunteer diver foundation that conserves underwater environments through education, advocacy and action.  
**Contact:** information@projectaware.org; www.projectaware.org

**RAMSAR – CONVENTION ON WETLANDS**

UN Convention on Wetlands that includes marine and coastal wetlands. **Contact:** Nick Davidson, davidson@ramsar.org; www.ramsar.org/types\_coral.htm

**REEFBASE**

Global coral reef database within WorldFish Center to gathers knowledge on coral reefs to facilitate analyses and monitoring of coral reef health for informed decisions on coral reef use and management. **Contact:** reefbase@cgiar.org; www.reefbase.org

**REEFBASE PACIFIC**

First regional focus of the ReefBase Project extended to Pacific and based in Fiji. **Contact:** Pip Cohen, p.cohen@cgiar.org; www.reefbase.org/pacific

**REEF CHECK FOUNDATION**

Global environmental NGO established to facilitate community education, monitoring and management of coral reefs, active in more than 70 countries.  
**Contact:** rcinfo@reefcheck.org; www.reefcheck.org

**RRRC – REEF AND RAINFOREST RESEARCH CENTRE**

Australian Government research initiative to ensure that targeted, focused research is delivered to appropriate end-users and management agencies.  
**Contact:** David.Souter@rrrc.org.au; www.rrrc.org.au

**SIDA & SAREC – SWEDEN**

The Swedish International Development Cooperation Agency (Sida) and its Department for Research Cooperation (SAREC) to assist developing countries alleviate poverty and achieve sustainable development. **Contact:** sida@sida.se; www.sida.se; www.wiomsa.org

**TNC – THE NATURE CONSERVANCY**

NGO with mission to preserve the plants, animals and natural communities that represent the diversity of life on Earth by protecting the lands and waters they need to survive. **Contact:** marine@tnc.org; www.nature.org/initiatives/marine

**UNEP – UNITED NATIONS ENVIRONMENT PROGRAMME**

UN Agency providing leadership and encouraging partnerships for environment by inspiring, informing, and enabling nations and peoples to improve their quality of life. **Contact:** unepinfo@unep.org; www.unep.org

**UNEP – CORAL REEF UNIT (CRU)**

The focal point within the UN system to guide and mobilize policies and actions to support the conservation and sustainable use of coral reefs.  
**Contact:** Stefan Hain, stefan.hain@unep-wcmc.org; http://coral.unep.ch until http://corals.unep.org

**UNEP – REGIONAL COORDINATING UNIT FOR THE CARIBBEAN ENVIRONMENT PROGRAMME (UNEP-CEP)**

Helps nations protect the marine environment and promotes sustainable development in the Wider Caribbean Region.  
**Contact:** rcu@cep.unep.org; www.cep.unep.org

**UNEP – WORLD CONSERVATION MONITORING CENTRE**

The biodiversity assessment centre of UNEP with a major coral reef focus. **Contact:** Kristian Teleki, Kristian.Teleki@unep-wcmc.org; www.unep-wcmc.org

**UNESCO WORLD HERITAGE CENTRE**

Established to assure the Secretariat of the 1972 World Heritage Convention and working towards a more integrated approach towards marine World Heritage sites. **Contact:** Marc Patry, m.patry@unesco.org; http://whc.unesco.org

**USCRTF – UNITED STATES CORAL REEF TASK FORCE**

Established by Presidential Executive Order in 1998 to lead U.S. efforts to preserve and protect coral reef ecosystems.  
**Contact:** coralreefweb@noaa.gov; www.coralreef.gov

**U.S. DEPARTMENT OF STATE**

The foreign policy arm of the United States Government with the Bureau of Oceans and International Environmental and Scientific Affairs promoting natural resource conservation, including coral reefs and coral reef ecosystems. **Contact:** www.sdp.gov/sdp/initiative/icri; www.state.gov/oes

**WORLD BANK – ENVIRONMENT DEPARTMENT**

International financial institution dedicated to the alleviation of poverty and committed to integrating environmental sustainability into its programs.  
**Contact:** Marea Hatzios, Environment Department, The World Bank, Mhatzios@worldbank.org ; www.worldbank.org/icm; info@gefcoral.org; www.gefcoral.org

**WORLD FISH CENTER**

Formerly known as ICLARM, WorldFish Centre is committed to contributing to food security and poverty eradication in developing countries.  
**Contact:** Jamie Oliver, j.oliver@cgiar.org; www.worldfishcenter.org

**WRI – WORLD RESOURCES INSTITUTE**

Environmental think tank that goes beyond research to find practical ways to protect the earth and improve people's lives.  
**Contact:** Elise King, eking@wri.org; www.wri.org/project/coral-reefs

**WWF – 'the global conservation organization'**

Largest and experienced NGO with a mission to stop degradation of the world's natural environment and conserving biological diversity.  
**Contact:** Anita Van Breda, anita.vanbreda@wwfus.org; or Helen Fox, helen.fox@wwfus.org; www.worldwildlife.org (USA); www.panda.org (worldwide)

## APPENDIX II: LIST OF ACRONYMS

|   |  |
|---|--|
| <b>AFCD:</b> Agriculture, Fisheries and Conservation Department [Hong Kong]           | <b>ERSST:</b> Extended Reconstructed SST   |
| <b>AGRRRA:</b> Atlantic and Gulf Rapid Reef Assessment                                | <b>ESCAP:</b> Economic and Social Commission for Asia and the Pacific [United Nations] |
| <b>AIDE:</b> Association d'Intervention pour le Développement et l'Environnement      | <b>FAO:</b> Food and Agriculture Organization  |
| <b>AIMS:</b> Australian Institute of Marine Science                                   | <b>FAST:</b> Faculty of Aquatic Science and Technology [Tanzania]                      |
| <b>AMESD:</b> African Monitoring of Environment and Sustainable Development           | <b>FBNMS:</b> Fagatele Bay National Marine Sanctuary [Fiji]                            |
| <b>AMO:</b> Atlantic Multi-decadal Oscillation  | <b>FDEP:</b> Florida Department of Environmental Protection                            |
| <b>APCRS:</b> Asia Pacific Coral Reef Symposium                                       | <b>FGBNMS:</b> Flower Garden Banks National Marine Sanctuary                           |
| <b>APEC:</b> Asia Pacific Economic Cooperation  | <b>FKNMS:</b> Florida Keys National Marine Sanctuary                                   |
| <b>ARVAM:</b> Agence pour la Recherche et la Valorisation Marines                     | <b>FLMMA:</b> Fiji Locally Marine Managed Area   |
| <b>BPAs:</b> Benthic Protected Areas  | <b>FRAs:</b> Fish Replenishment Areas  |
| <b>CARICOMP:</b> Caribbean Coastal Marine Productivity Program                        | <b>FSAs:</b> fish spawning aggregations  |
| <b>CBD:</b> Convention on Biological Diversity  | <b>FSM:</b> Federated States of Micronesia   |
| <b>CBOs:</b> community-based organisations  | <b>FWC:</b> Florida Fish and Wildlife Commission                                       |
| <b>CCA:</b> crustose coralline algae  | <b>FWI:</b> French West Indies   |
| <b>CCCC:</b> Caribbean Challenge to Conserve Corals                                   | <b>GBR:</b> Great Barrier Reef   |
| <b>CenSeam:</b> Census of Marine Life seamounts                                       | <b>GBRMP:</b> Great Barrier Reef Marine Park   |
| <b>CFMP:</b> Community-Based Fisheries Management Program                             | <b>GBRMPA:</b> Great Barrier Reef Marine Park Authority                                |
| <b>CI:</b> Conservation International   | <b>GCRMN:</b> Global Coral Reef Monitoring Network                                     |
| <b>CITES:</b> Convention on International Trade of Endangered Species                 | <b>GEF:</b> Global Environment Facility  |
| <b>COBSE:</b> Coordinating Body for the Seas of East Asia [UNEP]                      | <b>GIS:</b> Global Information System  |
| <b>COI:</b> Indian Ocean Commission   | <b>GLISPA:</b> Global Island Partnership   |
| <b>CoMarg-E:</b> Census of Marine Life continental margins                            | <b>GVI:</b> Global Vision International  |
| <b>CoRal Malaysia:</b> Malaysian Coral Reef Society                                   | <b>HERMES:</b> Hotspot Ecosystem Research on the Margins of European Seas              |
| <b>CORAL:</b> The Coral Reef Alliance   | <b>HERMIONE:</b> Hotspot Ecosystem Research and Man's Impact on European Seas          |
| <b>CORDIO:</b> Coastal Research and Development in the Indian Ocean                   | <b>HIMAG:</b> Hawaii Marine Algae Group  |
| <b>COTS:</b> crown-of-thorns starfish   | <b>IAS:</b> Institute of Applied Science   |
| <b>CPUE:</b> catch per unit effort  | <b>ICM:</b> Integrated Coastal Management  |
| <b>CRCP:</b> Coral Reef Conservation Program  | <b>ICRAN:</b> International Coral Reef Action Network                                  |
| <b>CRI:</b> Christensen Research Institute  | <b>ICRI:</b> International Coral Reef Initiative                                       |
| <b>CRISP:</b> Coral Reef InitiativeS in the Pacific                                   | <b>ICZM:</b> Integrated Coastal Zone Management  |
| <b>CRTF:</b> Regional Coral Reef Task Force   | <b>IFRECOR:</b> 'French Coral Reef Initiative'   |
| <b>CRTR:</b> Coral Reef Targeted Research and Capacity Building Project [Tanzania]    | <b>IMS:</b> Institute of Marine Sciences [Tanzania]                                    |
| <b>CRW:</b> Coral Reef Watch  | <b>INCO:</b> Iranian National Center for Oceanography                                  |
| <b>CTI:</b> Coral Triangle Initiative   | <b>IOC:</b> Intergovernmental Oceanographic Commission of UNESCO                       |
| <b>CWQG:</b> Coastal Water Quality Guidelines   | <b>IOI:</b> International Ocean Institute in Fiji                                      |
| <b>DEWHA:</b> Department of the Environment, Water, Heritage and the Arts [Australia] | <b>IPCC:</b> Intergovernmental Panel on Climate Change                                 |
| <b>DFO:</b> Department of Fisheries and Oceans [Canada]                               | <b>ISA:</b> International Seabed Authority   |
| <b>DHW:</b> Degree Heating Week   | <b>IUCN:</b> International Union for Conservation of Nature                            |
| <b>DMWR:</b> Department of Marine & Wildlife Resources                                | <b>JCU:</b> James Cook University [Australia]  |
| <b>EEZ:</b> Exclusive Economic Zone   | <b>JWRC:</b> Japan Wildlife Research Center  |
| <b>EFGB:</b> East Flower Garden Banks   | <b>KMFRI:</b> Kenya Marine and Fisheries Research Institute                            |
| <b>ENSO:</b> El Nino Southern Oscillation   | <b>KORDI:</b> Korean Oceanology Research and Development Institute                     |
|   | <b>KWS:</b> Kenya Wildlife Service   |

- LAS:** local action strategy
- LMMA:** Locally Managed Marine Area
- LMR:** living marine resources
- MAB:** Man and the Biosphere site of UNESCO
- MARAMP:** Marianas Research and Monitoring Program
- Mar-Eco:** Census of Marine Life North Atlantic mid-ocean ridge
- MARPOL:** International Convention of the Prevention of Pollution from Ships
- MFDC:** Mbegani Fisheries Development Centre [Tanzania]
- MOU:** memorandum of understanding
- MPA:** marine protected area
- MPRU:** Marine Parks and Reserve Unit [Tanzania]
- NAFO:** Northwest Atlantic Fishery Organization
- NAPs:** National Action Plans [PERSGA region]
- NEAFC:** Northeast Atlantic Fisheries Commission
- NEMA:** National Environment Management Authority [Kenya]
- NGO:** non-governmental organisation
- Ningaloo Research Program (NRP)** [Australia]
- NMFS:** ?? [US]
- NNWR:** Navassa National Wildlife Refuge
- NOAA:** National Oceanic and Atmospheric Administration [of USA]
- NPS:** National Parks Service [US]
- NSW:** New South Wales [Australia]
- NWHI:** north-western Hawaiian Islands
- NWR:** National Wildlife Refuges
- ODINCINDIO :** Ocean Data and Information Network for the Central Indian Ocean
- OGPP:** On-Ground Project Programme
- PAN:** Protected Areas Network
- PDO:** Pacific Decadal Oscillation
- PERSGA:** Program of the Environment of the Red Sea and Gulf of Aden
- PFSST:** Oceans Pathfinder Program
- PIFSC-CRED:** Pacific Islands Fisheries Science Center's Coral Reef Ecosystem Division
- PIPA:** Phoenix Islands Protected Area
- PNM:** Papahānaumokuākea Marine National Monument
- PNG:** Papua New Guinea
- ppm:** parts per million
- PRIAs:** US Pacific Remote Island Areas
- RAMP:** Rapid Assessment and Monitoring Program
- RAPs:** Regional Action Plans
- RECOMAP:** Regional programme for the sustainable management of the coastal zones of the Indian Ocean countries
- RFMO:** Regional fisheries management organisation
- RRRC:** Reef and Rainforest Research Centre
- RSA:** ROPME Sea Area
- SAR:** Special Administration Region [Hong Kong]
- scuba:** self-contained underwater breathing apparatus
- SEACMPA:** Southeast Asia Center for Marine Protected Areas
- SEAFO:** Southeast Atlantic Fishery Management Organization
- SECREMP:** South-east Florida Coral Reef Evaluation and Monitoring Project
- SEFCRI:** South-east Florida Coral Reef Initiative
- SEYMEMP:** Seychelles Marine Ecosystem Management Project
- SIDS:** small island developing states
- SIO:** Scripps Institution of Oceanography
- SOA:** State Ocean Administration [China]
- SocMon:** Socioeconomic Monitoring Initiative for Coastal Management
- SPREP:** Secretariat of the Pacific Region Environmental Programme
- SSTA:** Sea surface temperature anomalies
- SSTs:** sea surface temperatures
- TAFIRI:** Tanzania Fisheries Research Institute
- TCMP:** Tanzania Coastal Management Partnership
- TCRMP:** Territorial Coral Reef Monitoring Program
- TDA:** Trans-boundary Diagnostic Analysis
- TERANGI:** The Indonesian Coral Reef Foundation
- TNC:** The Nature Conservancy
- TRACES:** Trans-Atlantic Coral Ecosystem Study
- UAE:** United Arab Emirates
- UNCED:** United Nations Conference on Environment and Development
- UNEP/GEF SCS:** UNEP/Global Environment Facility South China Sea
- UNEP:** United Nations Environment Programme
- UNESCO:** United Nations Educational Scientific and Cultural Organisation
- UNF:** United Nations Foundation
- UNGA:** United Nations General Assembly
- UOGLM:** University of Guam Marine Lab
- UPMSI:** University of the Philippines Marine Science Institute
- US:** United States
- USA:** United States of America
- USCRTF:** United States Coral Reef Task Force
- USFWS:** US Fish and Wildlife Service
- USVI:** US Virgin Islands
- UV:** ultraviolet radiation
- VME:** Vulnerable Marine Ecosystem
- WAMSI:** Western Australian Marine Science Institution
- WCMC:** World Conservation Monitoring Centre
- WCPA:** World Commission on Protected Areas
- WCS:** Wildlife Conservation Society
- WFGB:** West Flower Garden Banks
- WMAs:** Wildlife Management Areas [PNG]
- WRI:** World Resources Institute
- WSSD:** World Summit on Sustainable Development
- WWF:** World Wildlife Fund
- WWF-SI:** WWF-Solomon Islands