Executive Summary

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Synopsis

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

Current Status of Coral Reefs

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

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

Global Threats to Coral Reefs

- Many coral reefs continue to recover after the 1998 El Niño/La Niña global coral bleaching event, with stronger recovery in well-managed and remote reefs; however, the recovery is not uniform and many reefs virtually destroyed in 1998 show minimal signs of recovery. This recovery could be reversed if the predicted increases in ocean temperatures occur as a result of increasing global climate change;
- There has been no recurrence of the major global-scale climate change pressures of 1998; although there have been some more localised bleaching events in 2000 and 2003 causing damage to reefs;
- The coral bleaching in 1998 was a 1 in a 1000-year event in many regions with no past history of such damage in official government records or in the memories of traditional cultures of the affected coral reef countries. Also very old corals around 1000 years old died during 1998. Increasing sea surface temperatures and CO_2 concentrations provide clear evidence of global climate change in the tropics, and current predictions are that the extreme events of 1998 will become more common in the next 50 years, i.e. massive global bleaching mortality will not be a 1/1000 year event in the future, but a regular event;
- Coral disease and major coral predators like the crown-of-thorns starfish continue to threaten reefs and evidence points to human disturbance as a contributing and catalytic factor behind these increases.

Coral Reef Management, Awareness Raising and Political Will

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

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

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

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

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

NA. Not applicable, as there were no losses in 1998.
Categories 4 and 5 are based on the very high to high risk, and the medium risk categories of the Reefs at Risk process (Box p 460).

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

The Executive Summary

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

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

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

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

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

- Wider Caribbean
- Great Barrier Reef

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

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

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

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

Recommendations for the Future of Coral Reefs

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

Status of Coral Reefs of the World by Regions

Two Global Calls to Action

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

Coral Reefs in A Historical Perspective

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

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

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

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

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

Two Major Coral Reef Regions: Wider Caribbean and Great Barrier Reef

This reports focuses on two regions for diametrically opposing reasons:

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

Great Barrier Reef

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

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

REZONING THE GREAT BARRIER REEF

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

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

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

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

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

The Wider Caribbean

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

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

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

LISTING OF CARIBBEAN CORALS AS ENDANGERED SPECIES

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

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

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

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

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

REGION-WIDE DECLINE OF CARIBBEAN CORALS

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

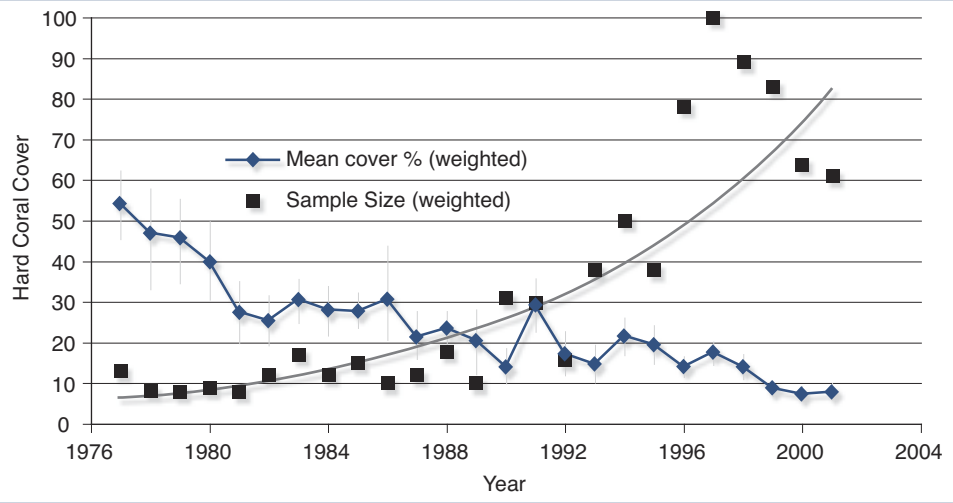
Virtually all sites showed a decline in coral cover over the study period with the loss averaging 5.5% in coral cover annually throughout the Caribbean. Such a 'meta' analysis based on uneven sized samples and markedly different monitoring methods requires close inspection. The researchers used several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

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

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

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

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



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

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

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

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

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

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

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

Threats and Stresses to Coral Reefs

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

Global Change Threats

- **Coral bleaching** – caused by elevated sea surface temperatures due to global climate change;
- **Rising levels of CO_2** – increased concentrations of CO_2 in seawater decrease calcification rates in coral reef organisms;
- **Diseases, Plagues and Invasives** – increases in diseases and plagues of coral predators that are increasingly linked to human disturbances in the environment.

Direct Human Pressures

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

The Human Dimension – Governance, Awareness and Political Will

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

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

WIDESPREAD CORAL BLEACHING IN THE CARIBBEAN: 1983-2000

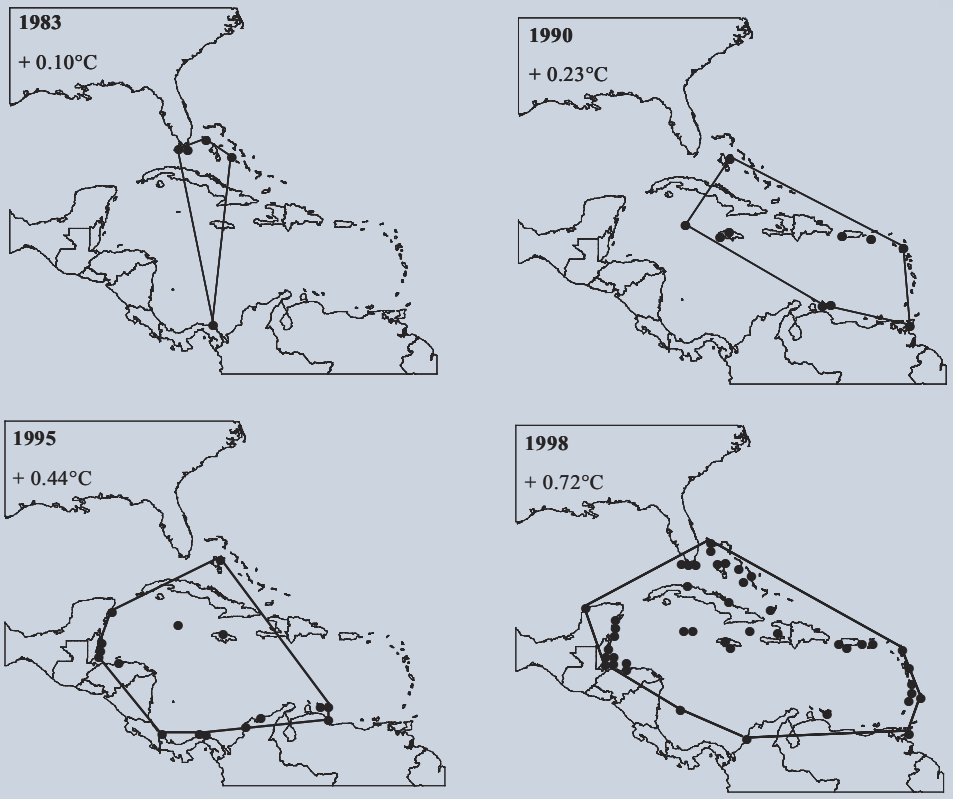
There is evidence that the timing and location of bleaching events in the wider Caribbean is increasing, although the number of sites reporting bleaching is highly variable among events. Bleaching incidence is very closely associated with variation in sea surface temperature (SST). Researchers from the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

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

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

The third category is more contentious: those stresses that are natural in origin, but are probably exacerbated by human activities. This category includes: stresses arising from global climate change, with coral bleaching and the potential that coral calcification will be reduced by rising concentrations of CO_2 in seawater; diseases of corals and other reef organisms; plagues of coral predators and other damaging animals; and invasive species that threaten to disturb the ecological balance on coral reefs by out-competing local species. These stresses are the theme for Chapter 1 Global Threats to Coral Reefs (p 67).

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



These maps show how the number of summer bleaching reports (black dots) in the Caribbean increases with regional sea surface temperature increases listed on the top.The most serious year for bleaching in the Caribbean was in 1998.

Global Climate Change

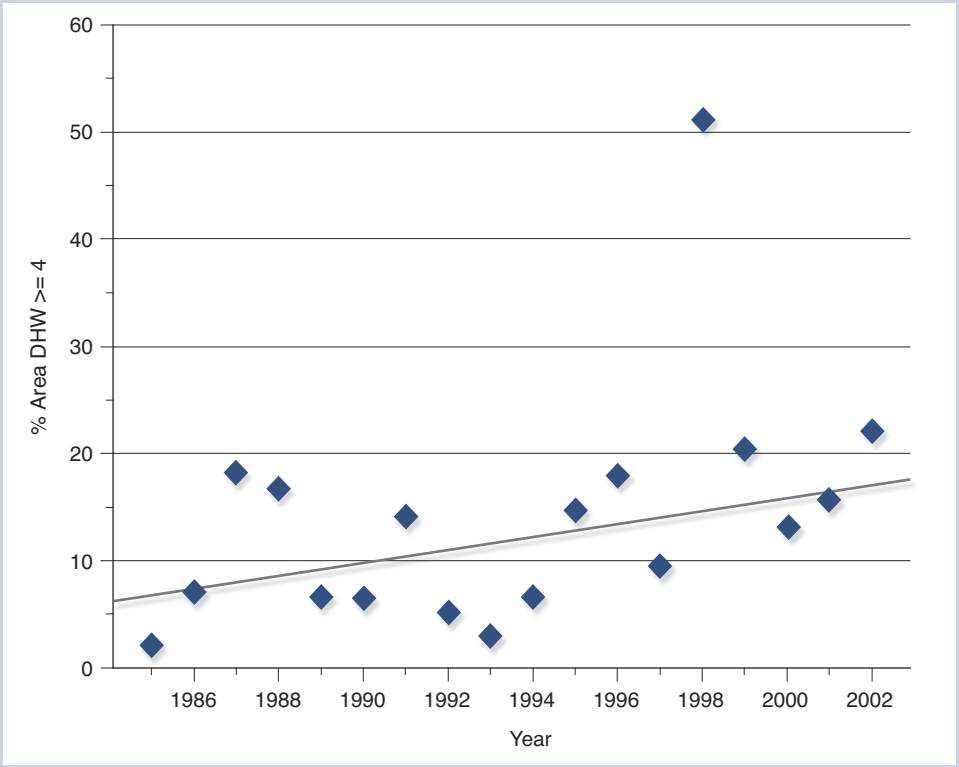
The major emerging threat to coral reefs in the last decade has been coral bleaching and mortality associated with global climate change (GCC), especially major El Niño/ La Niña events. The 1998 global coral bleaching event effectively destroyed 16% of the world's coral reefs, with most damage throughout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

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

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

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

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



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

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

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

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

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

The other major predicted changes from global climate change are: an increase in the frequency and intensity of tropical storms; more frequent and severe switches in global climate, such that El Niño - La Niña changes will be more regular; a rise in sea level; a potential shift in ocean currents; and an increase in the dissolved concentration of the greenhouse gas, carbon dioxide (CO_2) in seawater. There are suggestions that the first effect of more frequent and severe storms has already happened, but clusters like the recent severe storms in the Caribbean are known from historical records and no clear trend has emerged so far. It is apparent that the interval between El Niño events has shortened from about 12 years to less than 7 years, but the record is too short for confirmation. It is also too early to assess whether the large ocean currents will change. Sea level rise will not threaten the coral reefs, but will have potentially disastrous consequences for low coral islands, especially the atoll countries like the Maldives, Tuvalu, Marshall Islands and Kiribati.

One threat from the increase in greenhouse emissions is becoming more likely and could have very serious implications for coral reefs in the future. If the concentrations of CO_2 in the seawater continue to rise, there could be serious consequences for all calcifying organisms: tropical corals; cold water corals; calcifying algae; and organisms like foraminifera that are major producers of calcium carbonate in many marine ecosystems.

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

Diseases, Plagues And Invasives

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

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

CAN CORALS ADAPT TO COPE WITH GLOBAL WARMING?

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

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

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

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

EFFECTS OF SEAWATER CHEMISTRY CHANGES ON REEF CALCIFICATION

The threat of increasing atmospheric CO_2 on coral reef calcification poses a chronic and increasing threat to coral reefs. However, it is also a creeping and nearly invisible stress that receives much less attention than the more visible and acute coral reef problems like bleaching and diseases.

In 1992, Steve Smith and Bob Buddemeier cautioned that shifts in the carbonate system in seawater, driven by increasing concentrations of atmospheric CO_2, could have significant effects on the calcification rates of corals and marine algae. There have been numerous studies since then to test this hypothesis. Global-scale studies confirm that the oceans are sequestering about a third of all human induced CO_2 emissions, with the predicted effects on the carbonate system (lower pH, lower carbonate ion concentration). Experiments on reef building organisms in the laboratory and in large coral mesocosms (enclosed chambers with controlled environments) over hours to years confirm that calcification rates decline significantly under higher CO_2 concentrations; 10% – 40% reduction under doubled CO_2 concentrations. This is the level that is predicted to occur within 50 years. Studies on the skeletal density of *Porites* coral cores, however, do not reflect the expected post-industrial revolution decrease in calcification, but instead reflect rising ocean temperatures. A few experimental, but inconsistent, studies have tested the combined effects of seawater chemistry and temperature on coral calcification; it is clear that coral calcification rates are determined by both geochemical and biological controls. On the other hand, several studies show that carbonate sediments dissolve faster under increased CO_2 concentrations, and this side of the equation is not biologically controlled.

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

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

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

Direct Human Pressures on Coral Reefs

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

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

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

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

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

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

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

SUSTAINABLE CORAL REEF FISHERIES: POSSIBLE OR AN OXYMORON?

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

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

SUSTAINABLE FISHERIES MANAGEMENT IN CORAL REEF ECOSYSTEMS

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

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

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

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

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

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

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

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

Oceans Governance and Political Will

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

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

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

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

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

International Action or Inaction

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

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

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

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

Paradigm Shifts - New Coral Reef Initiatives

Management of Coral Reefs

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Rising Public Awareness of Coral Reef Problems

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

CORAL TRIANGLE HEADS EAST TO THE SOLOMON ISLANDS!

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

Recognition of Cold Water Coral Reefs

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

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

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

Recommendations for the Future of Coral Reefs

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

Action to Conserve Coral Reefs

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

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

Action to Improve Oceans Governance – or Turning the Tide

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

NEMO RETURNS

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

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

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

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

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

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

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

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

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

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

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

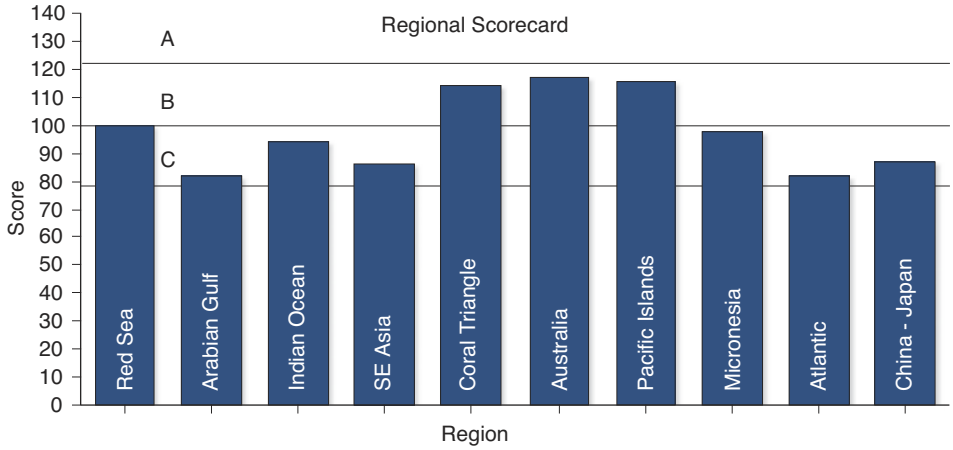
In addition, two action declarations are listed at the end of this Executive Summary. **The Okinawa Declaration** was prepared for the 10th International Coral Reef Symposium in Okinawa, Japan 28 June to 02 July, 2004 and endorsed by approximately 1,500 of the world's leading coral reef scientists, as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

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

Reef Check Summary of the Global Status of Coral Reefs: 2003

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

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



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

Status of Coral Reefs of the World By Regions

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Coral reefs and associated ecosystems are invaluable human treasures. They support the most diverse marine communities and beautiful seascapes on the planet, and provide wave-resistant structures and resources for local communities, fisheries, and tourism. However, coral reefs and associated ecosystems are now under serious threat of collapse because of over-fishing, development of the coastal zone, including dredging and landfill, and terrestrial run-off. Moreover, the increase in sea surface temperatures, the decrease in carbonate levels as well as sea-level rise, caused by increasing anthropogenic CO_2 in the atmosphere, all act synergistically to stress coral reefs, which lead to severe bleaching and extensive coral mortality. The degradation of coral reefs by local, regional, and global environmental stresses is at the very least destroying the health, function, and positive values associated with coral reefs, and at the worst leading to loss of this treasure.

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

A twin strategy must be taken over the longer term to reduce human induced climate change by reducing green-house gases, but at the same time a reduction in CO_2 must be matched by action to reduce immediate threats of declining water quality because of land-use changes and pollution, and mass exploitation of fish biomass. To achieve these goals, we recommend four key strategies: 1) achieve sustainable fishery on coral reefs, 2) increase effective marine protected areas on coral reefs, 3) ameliorate land-use change impacts, and 4) develop technology for coral reef restoration. Such efforts must be fostered and sustained through stewardship and cooperation among scientists, managers, policymakers, non-governmental organizations, and the general public. The task must be enhanced through international linkages among the principal global scientific body (International Society for Reef Studies [ISRS]), the main international management initiative (International Coral Reef Initiative [ICRI]), as well as leading international organizations (e.g. UNESCO, UNEP, IUCN) and NGOs.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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