

EXECUTIVE SUMMARY

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SYNOPSIS

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

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

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

- The Indian Ocean megathrust earthquake and tsunami struck on 26 December 2004 with enormous loss of life and disruption to Indian Ocean countries. There was considerable damage to the coral reefs of the Indian Ocean, but not at a scale comparable to human losses (Box p. ##);
- 2005 was the hottest year in the Northern Hemisphere since 1998 and this resulted in massive coral bleaching and hurricanes throughout the wider Caribbean in 2005 killing many corals and further damaging their reefs (Box p. ##);
- Degradation of coral reefs near major centres of population continues with losses of coral cover, fish populations and probably biodiversity. This is certainly happening around the ‘Coral Triangle’, the world’s centre for marine biodiversity (Box p. ##); and
- There is increasing evidence that global climate change is having direct impacts on more and more coral reefs with clear evidence that rising ocean acidification will cause greater damage into the future;

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

Countering such gloomy news, are some major advances:

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

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

- The International Coral Reef Initiative, currently co-chaired by Mexico and the USA, declared 2008 as the International Year of the Reef and developed major awareness raising campaigns around the world;
- The 11th International Coral Reef Symposium assembled 3500 scientists, managers and decision makers in Ft Lauderdale, USA, in July 2008 to bring the power of science to coral reef conservation (Box p. ##);

- Reef Check has organised 20 700 signatures on the ‘Declaration of Reef Rights’ petition launched in the International Year of the Reef;
- The Pew Environment Group is working with developed country governments to declare very large areas as no-take marine reserves, including the Coral Sea of Australia, the Northern Mariana Islands, the Chagos Archipelago in the Indian Ocean, and the Kermadec Trench, off New Zealand;
- The Coral Reef Targeted Research and Capacity Building for Management Program established 4 Centres of Excellence to build science capacity for management (Box p. ##)
- CRISP (Coral Reefs InitiativeS for the Pacific) has expanded operations into 17 Pacific island countries with considerable progress in raising capacity for reef management and socio-economic assessment (Box p. ##)
- The French and USA governments completed major national coral reef summary reports in 2008; the South West Pacific Node produced a regional report in 2007: the French and SW Pacific Node reports were presented in GCRMN format;
- The Global Environment Facility has allocated \$100 million as the Pacific Alliance for Sustainability to bring Pacific countries together to conserve their environments. Part of this money is going towards the Coral Triangle Initiative and the Micronesia Challenge;
- Germany has launched a new Biodiversity and Climate Research Centre based at the Senckenberg Research Institute in Frankfurt; it will have a significant coral reef component.

A series of Recommendations are listed below.

THE EXECUTIVE SUMMARY: THE STATUS OF CORAL REEFS IN 2008

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

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

RECOMMENDATIONS FOR ACTION TO CONSERVE CORAL REEFS

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

- **Urgently combat global climate change**— current rates of climate change pose the greatest threat to the long-term future of coral reefs and human coastal communities. We request that the world community, through their governments, agencies, NGOs, academic institutions and especially business establishments, collaborate to urgently reduce the current rate of emissions of greenhouse gases through reductions in energy use and the development of sustainable energy generating mechanisms or trading systems, and develop technologies to remove these gases, especially CO₂, from the atmosphere, to ensure that coral reefs will thrive in the next century.
- **Maximise coral reef resilience** (by minimising direct human pressures on reefs) – the second major threat to reefs derives from direct human activities: over-fishing and destructive fishing; sediment pollution from poor land use; runoff of nutrients and other pollution; and habitat loss through unsustainable development. Control of these threats, which are damaging reefs around the world especially in developing countries especially small island developing states, will improve the resilience of coral reefs in the face of climate change. These countries need assistance to improve local catchment and coastal management by upgrading capacity and providing funds to implement community-based management and develop alternative livelihoods that take pressures off reefs.
- **Scale up management of protected areas** – there is a need to improve the management of existing marine protected areas (MPAs) to accelerate restoration of depleted fish stock and protect coral reef goods and services that underpin coastal economies and livelihoods. This includes managing adjacent catchment areas to prevent nutrient and sediment pollution to create buffer areas that will reinforce MPA management activities.
- **Include more reefs in MPAs** – a proven and effective governance approach for conserving coral reefs and promoting sustainable use is to include them in effectively managed MPAs; preferably containing a significant proportion as fishery reserves or no-take areas, linked into a network of MPAs, and embedded within a larger governance framework. Developing countries will need assistance in expanding their MPA networks and establishing integrated coastal management (ICM) governance frameworks.
- **Protect remote reefs** – there are many coral reefs remote from continental land masses and human populations that, if they are protected, will be able to act as reservoirs of biodiversity to replenish depleted reefs. We recommend establishing more MPAs to include many of the remote island reefs, like those to the west of Hawaii, in Kiribati, and the Coral Sea east of the Great Barrier Reef. Developed countries may have the best resources in governance and enforcement to declare more large remote protected areas.
- **Improve enforcement of MPA regulations** – enforceable governance systems will be required to deal with the formidable problem of regulating access to managed ecosystems (including types and rates of resource exploitation). Many countries will

need assistance to establish effective enforcement systems that function in different marine coastal and marine environments and that do not undermine local cultural values and practices.

- **Help improve decision making with better ecological and socio-economic monitoring** – there is an urgent need to upscale monitoring, especially with increasing threats of climate change, to ensure that this information is provided to natural resource managers and decision makers so that appropriate actions can be taken to reduce threats to reefs and coastal communities.

STATUS NOW AND PREDICTIONS FOR THE FUTURE

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

Reefs Effectively Lost: Expert opinion backed by extensive monitoring and assessment data suggest that the world has lost the goods and services provided by 19% of the global coral reef area. These reefs are either so heavily degraded to be non-functional, or have been polluted or mined out of existence. The comparable figure was 20% in 2004. The decrease of 1% is due to strong coral reef recovery particularly in the Indian Ocean and Western Pacific after the devastating bleaching in 1998. However, recovery is stalled or weak where there are strong human pressures (over-fishing, pollution, sedimentation and unwise development). Countering that, there were major losses in the Wider Caribbean following similarly devastating bleaching, coral diseases and hurricanes in 2005, compounded by ongoing degradation from sediment and nutrient pollution and over-fishing and associated damage. Reefs in the heavily populated areas of Asia and the wider Caribbean report most losses. Reefs in the Persian Gulf have been devastated by major coral bleaching events and recently by extensive coastal developments along the Arabian Peninsula. Many reefs in this category are not irretrievably lost and will recover if human stresses can be reduced or if the devastating impacts of coral bleaching, diseases and predators are not repeated in the short-term.

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

Reefs at the Critical Stage: It is predicted that 15% of the world's coral reefs are under imminent threat of joining the 'Effectively Lost' category within the next 10–20 years, unless effective management actions are implemented. These predictions are based on observed trends over the past decade, on demographic increases in human population pressures, and assessments

of the effectiveness of current management. The regions with most 'Critical Stage' reefs have not changed from 2004 (predominantly Eastern Africa, South and South-east Asia and the wider Caribbean), where human pressures are regarded as high and increasing in the regional chapters below. This is a decrease from the 2004 estimate of 24% critically threatened.

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

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

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

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

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

Region	Coral Reef Area km ² ¹	Destroyed Reefs (%) ²	Reefs at Critical Stage (%) ³	Reefs at Threatened Stage (%) ⁴	Reefs at Low Treat level (%) ⁵
4. Red Sea	17,640	4	4	10	82
5. The Gulfs	3,800	70	15	12	3
6. East Africa	6,800	15	22	28	35
7. SW Indian Oc.	5,270	9	24	39	29
8. South Asia	19,210	25	20	25	30
9. SE Asia	91,700	40	20	25	15
10. E & N Asia	5,400	20	22	18	40
11. Australia, PNG	62,800	3	4	10	83
12. SW Pacific Ids	27,060	4	17	35	44
13. Polynesian Ids	6,733	3	2	5	90
14. Micronesian Ids	12,700	8	7	15	70
15. Hawaiian Ids	1,180	2	4	8	86
16. US Caribbean	3,040	21	31	19	29
17. North Caribbean	9,800	12	13	30	45
18. Central America	4,630	14	24	22	40
19. East Antilles	1,920	13	24	22	34
20. S Trop America	5,120	13	31	17	30
TOTAL	284,803	19	15	20	45

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

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

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

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

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

DAMAGING EVENTS FOR CORAL REEFS 2004 - 2008

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

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

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

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

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

Continuing Human Stresses on Coral Reefs: In the Status 2004 report, we listed the ‘Top 10’ threats to coral reefs under 3 categories. Sadly these continue in 2008 with no signs of abatement: **The ‘Global Change Threats’:** 1) coral bleaching from warmer seawater due to global climate change; 2) rising concentrations of dissolved CO₂, also a product of climate change; 3) diseases, plagues and invasive species. **The ‘Direct Human Pressures’:** 4) excess

sediments flowing off the land; 5) pollution by nutrients and chemicals, arising from poor land management, agriculture and industry; 6) over-fishing and destructive fishing, especially taking algal grazing fishes, the ‘immune system’ of a coral reef; 7) unsustainable and destructive development of coastal areas. ***‘Inadequate Governance, Awareness and Political Will’***: 8) increasing poverty and populations, and loss of agricultural land; 9) poor capacity for management and lack of resources, especially in small island countries; and 10) weak political will, and ineffective oceans governance. The last 7 threats are amenable to local action, aided by donor and developed countries providing some financial and logistical resources. The first 3 threats can only be solved by unified and concerted global action by all governments and people; the successor to the Kyoto conference in Copenhagen, December 2009 will determine whether the world is willing to take these necessary steps. The current fear is that the Global Financial Crisis of 2008 will provide an excuse for governments to avoid taking the necessary action in the short-term.

MAJOR NEW INITIATIVES IN CORAL REEF CONSERVATION

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

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

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

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

New Large MPAs: Two enormous MPAs in the Pacific were launched in 2006. The **Papahānaumokuākea Marine National Monument** was upgraded to highly protected status by the USA to take in the 356 893 km² of the Northwestern Hawaiian Islands Coral Reef Ecosystem Reserve, designated in 2000. The Government of Kiribati, with help from major NGOs, has created the world's largest marine protected area by enlarging the **Phoenix Islands Protected Area** (PIPA), in January 2008, to encompass 410 500 km². These eclipse the Great Barrier Reef Marine Park, established in 1975 and upgraded in 2004, which has 115 395 km² as no-take status out of the total 344 400 km². The Pew Environment Group has commenced a campaign to encourage developed country governments with adequate capacity and enforcement capability to declare very large ocean areas as no-take marine reserves. They have started with the Coral Sea of Australia and then seek to include the Northern Mariana Islands, the Chagos Archipelago in the Indian Ocean, and the Kermadec Trench off New Zealand;

World Heritage and Coral Reefs: In June 2008, the World Heritage Commission listed 6 large areas of New Caledonia for special protection including 15 743 km² of coral reefs. They acknowledged that these reefs are of global significance with a large concentration of biodiversity resources. The Republic of the Marshall Islands intends seeking World Heritage recognition for 9 atolls and one low reef island in 2009, and the government of Thailand is investigating a similar proposal for large areas of the Andaman Sea coast with substantial coral reefs.

POLAR BEARS AND CORAL REEFS

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

Climate change threatens both the Arctic and tropical coral reefs; from 90° North to the tropics around 0°. These two extremes illustrate that climate change will have dramatic effects at the extremes of the world's ecosystems, and all ecosystems between them. The threats to these two charismatic animals should serve as warning that global climate change will probably devastate ecosystems across the whole latitude range from the tropics to the Poles. These changes could lead to the extinction of the polar bear *Ursus maritimus* and to the extinction of many of the 700 species of coral. Polar bears and corals are evolutionarily very different: polar bears are at the tip of one mammal branch; while corals still resemble the first 'modern' corals that evolved about 35 million years ago. But both the bears and corals have evolved spectacularly well into their current environments, such that they are now totally dependent on these environments. The changes wrought by global climate to change those environments will threaten their existence and could result in extinction; just a few degrees of warming will be devastating. Kent Carpenter and 34 colleagues reported in *Science*, in July 2008, that one third of all tropical corals are considered as immediately threatened with extinction using IUCN Red List Criteria. The proportion of corals threatened with extinction has increased dramatically in recent decades and exceeds most terrestrial groups. Neither bears nor tropical corals will go extinct immediately; we will still be able to see some in zoos and aquaria which will symbolise the losses of these animals in the natural environment. Unlike the photo on the back cover, polar bears will not migrate to coral reefs (that can only happen with 'Photoshop').

CONSEQUENCES OF GLOBAL CLIMATE CHANGE FOR CORAL REEFS

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

- more coral bleaching from warmer oceans; 'the lottery';
- rising ocean acidification from more dissolved carbon dioxide (CO₂); 'the guarantee';
- more severe storms; probably 'another guarantee, we need insurance'; and
- rising sea levels that will drown some coral reef nations; 'another guarantee'.

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

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

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

NOAA satellites reveal tropical oceans have warmed at a significantly faster rate during the last 10 years (see p. ##), suggesting that there are only 8–10 years left to turn the tide because, if atmospheric CO₂ concentrations reach 450 ppm, seawater will become more acidic, thereby threatening the existence of coral reefs as we know them. Healthy and resilient coral reefs can respond vigorously to damage; but climate change stresses are eroding that resilience. For example, ocean acidification will prevent juvenile corals settling and make adults more fragile (see p. ##).

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

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

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

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

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

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

##); or over-exploitation of some species has also had a ‘downstream’ affect on the sea snakes, although fish populations appear healthy.

STATUS OF CORAL REEFS OF THE WORLD BY REGIONS

Indian Ocean

- **Persian Gulf, Arabian Sea and Gulf of Oman:** There has been minimal recovery in reefs of the Persian Gulf and Gulf of Oman after climate related devastation in 1996, 1998 and 2002, and massive cyclone ‘Gonu’ in mid 2007. Massive coastal development on the Arabian Peninsula side is also resulting in coral reef losses. These reefs appear amongst the most damaged in the world with the lowest predictions for recovery. Coral reef research and monitoring continues to lag behind other parts of the world, with Iran seeking to improve reef monitoring and management activities in the Node states;
- **Red Sea and Gulf of Aden:** The reefs continue to be in good health with gradual increases in reef awareness. There have been some localised losses from coral bleaching and crown-of-thorns starfish, but generally coral cover remains high to very high. Countries have developed action plans, however, there are major disparities in capacity and economics between relatively wealthy countries and those emerging from recent wars;
- **Eastern Africa:** Along the coastline there is a mix of reef recovery and reef degradation as management efforts are directed towards controlling the effects of rapidly growing populations and at involving local communities in coastal management. All countries are increasing their networks of MPAs in line with the WSSD calls above. Kenya and South Africa share the lead in monitoring activity, but all countries are improving management capacity and legislation;

Indian Ocean Islands: Reefs of the in the south-west of the ocean continue to recover after devastation in 1998. Some reefs of the Seychelles and Comoros that suffered major damage in 1998 have probably regained about half the lost coral cover; there has also been virtually no recovery on others. There have been major advances in awareness and the declaration of new MPAs, but the problems confronting governments and communities with increasing development and populations continues to nullify positive activities. There has been a reduction in monitoring sites and the flow of information, and little is known on the status of seagrass and mangrove areas.
- **South Asia:** The situation in South Asia continues as a mix of reef decline as large human populations further damage the coral reefs, adding to damage that occurred in 1998; governments are increasing their efforts, but will they be too late? However, there has been amazing recovery of the reefs of the western Maldives, Chagos, Lakshadweep Islands of India and on north-west Sri Lanka, with seemingly locally extinct corals making major recoveries e.g. some reefs have gone from less than 5% coral cover to 70% in 10 years. The 2004 Indian Ocean earthquake and tsunami caused significant reef damage at some sites, but many are recovering.

Asia and Australia

- **South-east Asia:** The Coral Triangle Initiative in Indonesia, Philippines, Eastern Malaysia, Papua New Guinea, Timor Leste and the Solomons has been initiated in an attempt to reverse the massive degradation of these reefs at the global centre of

reef biodiversity. We include the first data for Timor Leste. Over-fishing, increasing sedimentation and urban and industrial pollution from rapid economic development are accelerating reef degradation faster than governments and NGOs can implement conservation. More than 50% of the region's mangroves have been lost.

- **North-east Asia:** Coral reefs have shown an overall decline since 2004 with most reefs coming under significant levels of human pressures, as well as bleaching and COTS stress. There are a few reefs with high coral cover, such as Dongsha Atoll between Taiwan and China. Increased coral reef monitoring and research, including the establishment of a regional database, is occurring in Japan, Hong Kong, Taiwan and Hainan Island in China, and the region is stimulating more awareness and cooperation by having held the Asia Pacific Coral Reef Symposium in Hong Kong in 2006 and planning another for Thailand in 2010.
- **Australia and PNG:** Reefs of Australia continue to be well managed and relatively stable with no major climate change or cyclone events damaging the reefs since 2004. Management continues to set the benchmark for best practice, both in Eastern Australia on the Great Barrier Reef and, more recently, off Western Australia. Particular features are the effective partnerships between coral reef science and management. The situation is the reverse in Papua New Guinea with inadequate coral reef conservation and monitoring, with most of this being performed via large NGOs working with local communities. PNG still has vast areas of healthy and biodiversity-rich coral reefs but human pressures, both from within and external, are increasing.

Pacific Ocean

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

- **US Pacific:** The USA recognised the global importance of the North-west Hawaiian Islands and have declared the Papahānaumokuākea Marine National Monument MPA. Management is increasing around the Main Hawaiian Islands, but over-fishing and sediment pollution continue as major threats. The depletion of aquarium species is being addressed through the establishment of industry recognised MPAs;

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

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