PART I

Setting the stage

1

Status of coral reefs of the world: summary of threats and remedial action

CLIVE WILKINSON
Australian Institute of Marine Science

INTRODUCTION

While the history of active coral reef research stretches back over 100 years, the concern for the declining status of coral reefs is relatively recent, probably less than 25 years. The first major attempt to alert the global coral reef science community to the threats posed to coral reefs was in 1981 by Edgardo Gomez, who subtitled the 4th International Coral Reef Symposium in Manila, May 1981, as *The Reef and Man* (Gomez, 1982). Similarly Bernard Salvat and David Stoddart raised the alarm in 1982 (Salvat, 1980, 1982; Stoddart, 1982). At this time, most coral reef researchers worked from field stations during vacations; field stations specifically chosen that were adjacent to healthy and flourishing coral reefs seemingly not affected by human impacts. There was a small group of coral reef scientists who were working in developing countries, however, who were aware of an impending crisis for coral reefs.

Since that 1981 Symposium, there has been a steady increase in the involvement of coral reef scientists in the applied aspects of coral reef management (summarized in Knowlton, this volume). A paper published by Don Kinsey in 1988 succinctly summarized the stresses to coral reefs (Kinsey, 1988). Similarly there were other reports of localized damage to coral reefs by coral reef scientists (Brown, 1987; Gomez, 1988; Pauly and Chua, 1988; Grigg and Dollar, 1990), but it was not until 1992 that global attention was alerted to the threats facing coral reefs. That was the year of

Coral Reef Conservation, ed. Isabelle M. Côté and John D. Reynolds.
Published by Cambridge University Press.

the United Nations Conference on Environment and Development in Rio de Janeiro and the 7th International Coral Reef Symposium in Guam. The two plenary addresses in Guam focused on the threats facing coral reefs, with alarming predictions of a bleak future if remedial action was not taken (Buddemeier, 1993; Wilkinson, 1993). Immediately following this symposium, Bob Ginsburg organized a landmark conference in Miami that recognized the apparent crisis facing coral reefs, although there was insufficient information for a full assessment (Ginsburg, 1993). One of the reports of decline was the collapse of the Discovery Bay coral reefs of Jamaica, a 'model' coral reef studied by many coral reef scientists (Goreau, 1959; Hughes, 1989, 1994). These conferences all acted as catalysts to initiate the International Coral Reef Initiative (ICRI) in 1995, the Global Coral Reef Monitoring Network (GCRMN) in 1996, and Reef Check in 1998 (Hodgson, 1999). The decline of coral reefs was confirmed with 14 reports presented at the 8th International Coral Reef Symposium in Panama, 1996, the findings of which were used to produce the first *Status of Coral Reefs of the World: 1998* report by the GCRMN (Wilkinson, 1998).

There is indeed a crisis facing coral reefs with a range of stresses acting sometimes in isolation, but usually in concert, in many parts of the world. This chapter is a summary of the *Status of Coral Reefs of the World: 2004* report that was finalized in early December 2004 based on more than 240 contributors from 96 countries (Wilkinson, 2004). The report was published by the Australian Institute of Marine Science and the Global Coral Reef Monitoring Network and is available online at www.aims.gov.au or www.gcrmn.org.

CORAL REEFS IN A HISTORICAL PERSPECTIVE

It is instructive to review the recent history of coral reefs during the last 10 000 years of human activities. Much of this overview is derived from the research of Jeremy Jackson and colleagues (Jackson, 1997; Jackson *et al.*, 2001; Pandolfi *et al.*, 2003). Additional historical information is presented by Precht and Aronson (this volume).

10 000 years ago

The history of modern coral reefs can be traced readily back about 10 000 years when sea levels were rising as the ice melted to end the Pleistocene. Over a period of about 5000 years, sea levels rose 110 to 120 m (approximately 240 cm per 100 years compared to the current predicted rate of

approximately 50 cm per 100 years). The early Holocene was a period of rapid coral reef growth as corals settled on limestone and other hard substrata in tropical and subtropical regions. The Pleistocene also facilitated human migrations during low sea level. These early human populations undoubtedly exploited coral reef resources, seen in archaeological evidence of major harvesting of fishes, molluscs, dugongs, manatees and especially turtles in most areas. That rate of exploitation most probably increased as human populations grew and technology increased (Jackson *et al.*, 2001).

1000 years ago

Human populations had occupied most available land adjacent to coral reefs, including the vast expanses of the Pacific Ocean, with the exception of some Indian Ocean islands and very remote islands and atolls. These peoples continued to exploit coral reef resources for food and building materials. By current standards, most of these reefs would have been regarded as predominantly pristine with healthy corals, and large, well-structured fish and invertebrate communities. The available human technology allowed the exploitation of some of the larger fauna (turtles, dugongs and giant clams) in shallow water, but there was little capacity to harvest organisms in deeper water. These indigenous populations remained relatively small and some small island populations were developing traditional management of coral reef resources to ensure sustainability.

100 years ago

The consensus opinion of authors from the 94 countries included in the 2004 report (Wilkinson, 2004) is that 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 exceptions again were the large fauna: dugong, manatee, turtles and giant clams. Pollution was not regarded as a problem and sediment damage was limited, although the land clearing in the tropics for agriculture was increasing. There was no concept of a 'coral reef problem' and little consideration was given to the need for management of the resources, except possibly pearl shell in the Pacific.

Since 1992

The first global assessment of coral reefs produced by Sue Wells and colleagues in 1988 contained many references to degraded reefs (Wells, 1988).

The World Environment Summit at Rio in 1992 set an agenda for global marine conservation with Chapter 17 of Agenda 21; then there were alarming predictions about the future of coral reefs (Wilkinson, 1993). There followed a landmark conference in Miami which concluded that, while there was insufficient information to assess the status of the world's coral reefs, there was an apparent crisis facing coral reefs (Ginsburg, 1993). The ICRI started in 1995 as a means of stimulating diplomatic and international agency focus on coral reefs, especially because of their considerable strategic and economic importance. The GCRMN and Reef Check followed soon after to document this apparent global decline in coral reef status.

2004

The collective opinions of the 240 authors who contributed to the *Status of Coral Reefs of the World: 2004* report (Wilkinson, 2004) are summarized in Table 1.1. The estimates 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 seriously damaged by coral bleaching in 1998 are either recovering well or have recovered;
- approximately 24% of the remaining reefs in the world are under imminent risk of collapse through human pressures; and
- a further 26% of the remaining reefs are under a longer-term threat of collapse.

The losses of the reefs are attributed to direct damage from human activities on coral reefs: poor land management practices that result in the release of sediments, nutrients and other pollutants; over-fishing and particularly fishing with destructive methods; coral predators such as the crown-of-thorns starfish and coral diseases; and increasing water temperatures that result in lethal coral bleaching and exacerbated coral diseases.

A similar assessment of global reef status was obtained by Reef Check, a predominantly volunteer monitoring programme that has obtained data from more than 750 coral reefs in 70 coral reef countries in 2003. They report that the living coral cover lost during the 1998 bleaching event has been largely replaced by new growth, although often very variable in extent and location. Reef Check reports that many key human impact indicators, such as food fish, continue to decline, with the number of sites not reporting medium- to large-sized serranids and a key target species in the Indo-Pacific, the humphead wrasse (*Cheilinus undulatus*), having

Table 1.1. A summary of the current status of coral reefs in 17 regions of the world designated as Nodes within the GCRMN. These estimates were developed by the authors of the chapters in Wilkinson (2004), and from the Reefs at Risk analyses (Bryant *et al.*, 1998; Burke *et al.*, 2002; Burke and Maidens, 2004). These assessments should be regarded as indicative, because there are insufficient coral reef monitoring data for many regions to make definitive statements on losses and authoritative predictions for the future. The proportion of reefs in column 3 has increased from 11% reported in Wilkinson (2000), with the addition of more damaged reefs and those that have not recovered from 1998 (column 4)

Chapter number and region of the world	Reef area ($km^2 \times 1000$)	Destroyed reefs (%)	Reefs recovered / reefs destroyed in 1998 (% / %)	Reefs at critical stage (%)	Reefs at threatened stage (%)
4. Red Sea	17.64	4	2 / 4	2	10
5. The Gulfs	3.80	65	2 / 15	15	15
6. East Africa	6.80	12	22 / 31	23	25
7. SW Indian Ocean	5.27	22	20 / 41	36	31
8. South Asia	19.21	45	13 /65	10	25
9. SE Asia	91.70	38	8 / 18	28	29
10. E and N Asia	5.40	14	3 / 10	23	12
11. Australia, PNG	62.80	2	1 / 3	3	15
12. SW Pacific Islands	27.06	3	8 / 10	18	40
13. Polynesian Islands	6.73	2	1 / 1	2	3
14. Micronesian Islands	12.70	8	1 / 2	3	5
15. Hawaiian Islands	1.18	1	NA	2	5
16. US Caribbean	3.04	16	NA	56	13

(*cont.*)

Table 1.1. (*cont.*)

Chapter number and region of the world	Reef area ($km^2 \times 1000$)	Destroyed reefs (%)	Reefs recovered / reefs destroyed in 1998 (% / %)	Reefs at critical stage (%)	Reefs at threatened stage (%)
17. North Caribbean	9.80	5	3 / 4	9	30
18. Central America	4.63	10	NA	24	19
19. East Antilles	1.92	12	NA	67	17
20. S Tropical America	5.12	15	NA	38	15
Total	284.30	20	6.4 / 16	24	26

Notes:
Column 1: The countries in each region are listed in Wilkinson (2004).
Column 2: Coral reef area from the *World Atlas of Coral Reefs* (Spalding *et al.*, 2001).
Column 3: Reefs 'destroyed' with 90% of the corals lost and unlikely to recover soon.
Column 4: Proportion of reefs recovered of the losses in 1998 from global coral bleaching (% / %).
Column 5: Reefs at a critical stage with 50% to 90% loss of corals, likely to join those in the Destroyed reefs column in 10 to 20 years.
Column 6: Reefs threatened with moderate signs of damage, 20% to 50% loss of corals and likely to be added to the Destroyed reefs column in 20–40 years.
NA. Not applicable, as there were no climate change related losses in 1998.
Columns 4 and 5 are based on the very high to high risk (combined), and the medium risk categories of the *Reefs at Risk* process (Burke and Maidens, 2004).

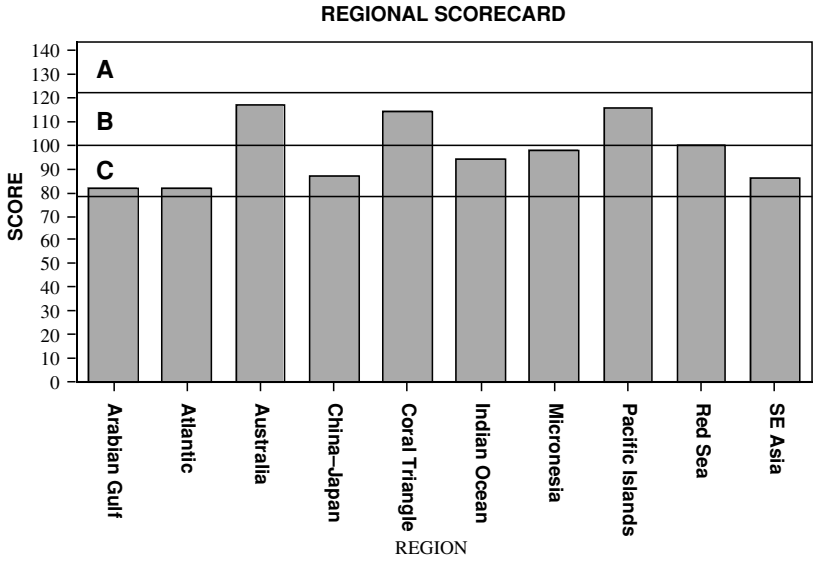

Figure 1.1 Sum of the 18 indicator grades (A = 4, B = 3, etc.) in each region from Reef Check surveys in 2002–2003; a perfect score would be 144. (Source: Gregor Hodgson, Reef Check.)

increased from 90% to 95% from 1997 to 2003 (Hodgson and Liebeler, 2002; www.ReefCheck.org). A regional scorecard based on the 18 categories of data recorded by Reef Check shows variation among regions of the world in the health of coral reefs (Fig. 1.1). This shows that Australia, the Pacific Islands and Coral Triangle (between Indonesia, the Philippines and Papua New Guinea) had the least damaged reefs in 2003, whereas the Arabian Gulf and Atlantic reefs were in the worst condition.

STATUS OF CORAL REEFS OF THE WORLD BY REGIONS

The following sections are summaries of the more detailed chapters in the *Status of Coral Reefs of the World: 2004* report (Wilkinson, 2004). The information on damage from the major tsunami of 26 December 2004 is derived from reports received after these chapters were written.

The Red Sea and Gulf of Aden (Kotb *et al.*, 2004)

The Red Sea reefs continue to be in relatively good health, because there are few 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 without sufficient controls on sewage pollution and sediment runoff, coral bleaching and the crown-of-thorns starfish are the major future problems. The political awareness and will for conservation are 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 (Regional Organization for the Protection of the Marine Environment Sea Area) (Rezai *et al*., 2004)

The reefs off the Arabian Peninsula have shown little recovery after they were largely destroyed during severe coral bleaching events in 1996 and 1998. The only recovery is larvae recruiting from reefs in deeper water that were less affected; however, there is an apparent shift in the recruiting coral species to lower-profile, slow-growing and more resistant species (e.g. species of *Porites, Favia* and *Cyphastrea*). Prior oil exploitation, shipping activities, and military conflicts that had resulted in some major oil spills have caused minimal previous damage. Near-shore reefs on the Iranian coast have also been affected by bleaching, but at a low level, whereas some of the offshore reefs in deeper water retain healthy corals. Awareness is increasing in this region; however, there are some major development projects that are destroying coral reefs. A monitoring network was formed in late 2003 with Iran as the host country.

East Africa (Obura *et al*., 2004)

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 people 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 marine protected areas (MPAs) in the last two to four years, due to national and regional initiatives, and greater commitments to increase the area of MPAs and improve fisheries management (see McClanahan, this volume). Regional and international NGOs are assisting communities in developing 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. Damage to the coral reefs from the tsunami was relatively minor (D. Obura, pers. comm.).

South West Indian Ocean islands (Ahamada *et al.*, 2004)

There has been some recovery of the coral reefs damaged in 1998. However, recent bleaching damage to the new coral recruits is slowing recovery (see also Sheppard, this volume). 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 (Madagascar, Mauritius, Réunion) 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 programmes 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 are expanding and providing information for governments. Damage to the coral reefs from the tsunami was relatively minor (D. Obura, pers. comm.).

South Asia (Rajasuriya *et al.*, 2004)

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 great 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. There was massive damage in India, the Maldives and Sri Lanka from the tsunami, but damage to the reefs was less important than damage to shorelines and coral islands. Some reefs