

CORAL REEF STATUS AROUND THE WORLD: WHERE ARE WE AND WHERE DO WE GO FROM HERE?

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ABSTRACT

The Philippines-hosted International Coral Reef Initiative Workshop, June 1995, began a concise global summary of coral reef ecosystem status. *State of the Reefs* and six regional status reports evaluated environments, threats and opportunities for improved management. Regional meetings, held Jun. 1995 - Apr. 1996, provided greater focus on the regions and improved regional assessments. The ICRI *Framework for Action* calls for regular reviews of these important ecosystems and of actions toward the goal of increasing sustainability to be shared with international bodies and conventions. Global and regional programs must coordinate efforts to help countries relieve human pressure on reef ecosystems around the globe. This presentation introduces the status reports, discusses the interrelationships between these organizations and plans for developing the global monitoring network and delivering future assessments.

INTRODUCTION TO THE PROBLEM

There is a growing consensus among coral reef scientists that coral reefs around the world are in a state of decline (Ginsburg 1994; Jameson et al. 1995). However, it is currently very difficult to determine the extent of threats, rates of decline and the consequences in terms of global resources and impacts on dependent communities. This paucity of information limits our ability to plan strategies and effectively approach the threats to coral reefs on a global and regional basis. We need a coordinated approach to improve our understanding of the current condition of reefs globally.

Recent advances in international and regional programs have improved our understanding of reef system changes. However, these have only begun to scratch the surface. Information still needed at global, regional and national levels in a variety of areas, includes:

- the extent, distributions and variability of coral reef systems,
- the degree and nature of human and natural stresses impacting coral reefs,
- the degree and nature of human dependence on coral reefs,
- the expected values for indicators to assess coral reef health,
- the expected responses of coral reefs to increasing levels of stress, and
- the degree to which the health of coral reefs can be accurately assessed through in situ and remotely sensed monitoring approaches.

Threats to reefs

Many stresses affecting coral reefs have been well-documented, such as dredging, siltation, organic pollution, oil pollution, sewage blast-fishing, fish poisoning, anchor damage, construction of infrastructure on reefs and stresses from tourism (Johannes 1975; McManus and Wenne 1981; Salvat 1987; McManus et al. 1992; Hawkins and Roberts 1993; Richmond 1993; Gomez et al. 1994; Jameson et al. 1995). In all cases, further work is needed before effects on coral reefs can be predicted with confidence under real-world conditions. While we are improving our understanding of stress effects, we still cannot determine the causes of many reef declines or accurately predict their future fate.

It is a difficult conundrum that extractable resources are important in the human value of reefs, but many forms of extraction harm the reefs themselves. Worse, we understand little of the effects of many types of fishing. The damage caused by muro ami, explosives and sodium hypochlorite bleach are understood (Salvat 1987; Seila et al. 1991), but the effects on corals of sodium cyanide, increasing in popularity as a fish poison, are virtually unknown. Increasing competition has led many trawlers to systematically destroy coral communities to enlarge their fishing grounds and errant or "ghost" fishing gear can have demonstrable impacts. Coral reef fisheries are often dominated by large pools of economically disadvantaged fishers who are then maintained at marginal levels of existence by competition from other entrants, leading to Malthusian overfishing - the tendency for fishers to increasingly use fishing methods destructive to the environment and to themselves (Fauly 1990; McManus et al. 1992). Decreasing resource availability leads to greater desperation in a spiral of devastation.

Less well understood are the influences of natural stress on reef systems. Particularly, the dramatic effects of the 1982-83 El Niño and recent coral bleaching have raised concern over climate impacts on corals (Brown and Suharsono 1990; Glynn 1990; D'Elia et al. 1991). While some bleaching has been attributed to climate forcing, connections to anthropogenic climate change are, as yet, unsubstantiated (Glynn 1991; Smith and Buddemeier 1992). It is likely that climatic stress is of less immediate concern than direct anthropogenic stress (D'Elia et al. 1991; Wilkinson and Buddemeier 1994) and the real problem is the cumulative effect of interacting stresses on the system.

Although it is now clear that coral reef decline is a global problem, it is not possible to determine how great the problem is. There is no central repository of coral reef information, and no means by which coral reef data from around the world can be summarized, compared or evaluated for global trends.

Our limited knowledge

While the most widely cited estimate of the world's coral reef area is 617,000 km² (Smith 1978), others have calculated estimates as low as 230,000 km² (Spalding in press) and as high as 1,500,000 km² (Copper 1994; J. Kleypas pers. comm.). Spalding suggests that reef area estimates are likely to span an order of magnitude based solely on the definition of reef that is used and results of modeling by Kleypas and others are strongly dependent upon parameterization. Of these reefs, perhaps 10% have already been degraded beyond recovery and another 30% are likely to be lost within 10-20 years and another 30% within 20-40 years (Wilkinson 1992) - most without ever being well studied. In fact, the vast body of research on coral reefs has concentrated on a few hundred coral reefs which are either convenient to access or special significance due to size or historical activities. Most of these have been near surface or surface-breaking. Much more research is needed on non-depositional coral communities and subsurface shelf reefs and pinnacle reefs. Although deep reefs and coral communities have been known since before the time of Darwin, they have often been glossed over or omitted entirely in many discussions of coral reef ecology.

All of these reef types and their variety of diversity is essential to properly functioning ecosystems. Just as simple predator-prey relationships in low diversity systems are subject to dramatic population swings, coral reefs with low diversity are subject to dramatic changes. Low diversity coral reef ecosystems in the eastern Pacific have suffered dramatic erosion and little recovery since initial mortalities during the 1982-83 El Niño (Eakin 1996; Reaka-Kudla et al. 1996). This contrasts with the much more rapid recovery seen in the Indo-Pacific after outbreaks of *Acanthaster planci* (Colgan 1981). Such differences led a group to conclude in 1993 (Done et al. in press) that the high biodiversity on coral reefs is necessary for maintenance of their ecosystem function. Unfortunately, little is really known about the diversity of these systems or the changes in diversity that result in system instability.

OUR IMPROVING KNOWLEDGE

Early developments

Major advances in our understanding of reefs have occurred in the last decade. Wells compiled the first comprehensive, global documentation of the location, condition, threats and published studies of known reefs (UNEP/IUCN 1988). This provided a baseline from which studies of the condition of reefs worldwide could be built, but was a static product. A mechanism was needed to provide for regular updates. Apparent increases in reef stress and potential reef declines came to the attention of a broader audience when frequent, widespread coral bleaching began in the 1980s (D'Elia et al. 1991).

By the early 1990s, threats to coral reefs became a marine parallel to rain forest loss and initial data from a regional program, ASEAN-Australia, demonstrated widespread, human-induced threats (Wilkinson 1992). With the possibility of global decline now apparent, a meeting on the health, hazards and history of reefs began to document the global patterns of reef declines (Ginsburg 1994). Data from the newly activated Caribbean Coastal Marine Productivity (CARICOMP) program demonstrated a similar pattern of decline (Smith and Ogden 1994, CARICOMP in press). Further, qualitative CARICOMP data showed that, of 14 sites reporting, there was no change in coral cover in five sites that were protected by control of fishing. They suggested that this result agreed with findings of Hughes (1994) from 17 years of monitoring on the north shore of Jamaica (Co-Chairmen of the Steering Committee and Ogden 1994) and felt that over-fishing was a key controlling agent on Caribbean reefs.

The International Coral Reef Initiative

Rising out of a developing U.S. Initiative, the concept of an International Coral Reef Initiative (ICRI) was proposed at various international fora in 1994. Building on existing programs and expertise, ICRI was designed to provide a focus on the plight of reefs and on the actions necessary to reverse their degradation. ICRI began with international partners that included eight countries, three United Nations organizations, intergovernmental organizations, multilateral development banks and non-governmental organizations. Its objectives call for:

- strengthening commitment to and implementation of programs at all levels to conserve, restore and promote sustainable use of coral reefs and related ecosystems;
- each country and region to incorporate into existing development plans, management provisions for protection, restoration and sustainable use of coral reefs;
- strengthening capacity for development and implementation of policies, management, research and monitoring of coral reefs and related ecosystems; and

- establishing and maintaining coordination of international, regional and national research and monitoring programs including the Global Coral Reef Monitoring Network, to ensure efficient use of scarce resources and a flow of information relevant to coral reef management (ICRI 1996).

During 29 May - 2 June, 1995 the Philippines hosted the ICRI Workshop at which participants from 44 countries developed a consensus framework for achieving sustainable management of coral reef ecosystems. They endorsed a *Call to Action* that highlights the value of and threats to coral reefs and developed a *Framework for Action* that builds upon the principles and processes established by Agenda 21 (UNCED 1992) and advocated in the *Call to Action* (ICRI 1995). The Framework provided more specific recommendations for international actions and for use in the development of regional and national action plans.

There is a clear recognition that community-based management or co-management of coral reef resources is a strong factor in success. Monitoring and management at the global level will not be effective unless supported by regional and national commitments. Since June 1995, a series of ICRI Regional Workshops continued the process begun during preparations for the International Workshop. Five regional meetings have been held through April 1996, with the final planned for early 1997. These meetings have provided a focus on the status, threats and needs of the regions and have helped improve regional assessments. Additionally, many nations have developed national CRI efforts (Crosby et al. 1995; ICRI 1996). The results of these meetings have been shared with United Nations bodies and conferences, particularly the Commission on Sustainable Development.

The State of the Reefs and ICRI regional reports

A report on *The State of the Reefs* was prepared for the ICRI Workshop (Jameson et al. 1995). This report summarized, in broad scale, the status and trends of coral reefs worldwide, the consequences of coral degradation to human populations and some of the existing management and research programs. The report found that human activities have damaged reefs in over 93 countries, with reefs at greatest risk in southern and Southeast Asia, eastern Africa and the Caribbean. Rapid population growth and migrations to coastal areas, overexploitation of reef resources, excessive pollution and poor land use practices have been the primary causes. Unfortunately, the status and trends of complete coral reef ecosystems have never been comprehensively evaluated and most coral reef surveys have been limited to discrete reefs, few species and brief or irregular time periods.

While the *State of the Reefs* report provided an overall summary, a series of six regional reports prepared for the ICRI Workshop provided greater detail (Anon. 1995; Foua 1995; Ngole et al. 1995; Smith 1995; White and Rajasuriya 1995; Woodley 1995). These reports each summarized the distribution of, condition of, and problems facing reefs in countries from their region. They considered the management structure and protection systems in their countries and international activities that join them together. Finally, they identified priorities for management, capacity-building and research and monitoring. Because of varying degrees of information in each region, some represented a slight update of the information from Wells' compilation (UNEP/IUCN 1988), while others provided comprehensive discussions that benefitted from numerous regional meetings over recent years. These reports are being updated through the ICRI Regional Workshops and the analysis of new data and are being presented in this session of the 8th International Coral Reef Symposium (ICRS).

NEW DATA GATHERING**Developing a global system**

In 1991, an experts group began meeting under the auspices of the Intergovernmental Oceanographic Commission (IOC) and other international bodies with the purpose of discussing a program for global monitoring (IOC 1991). At the 7th International Coral Reef Symposium in Guam the plan for a Global Coral Reef Monitoring Network (GCRMN) as a part of the IOC Global Ocean Observing System was endorsed. Representatives from some 30 countries, 40 institutions, and several organizations and existing networks agreed on the need for a coordinated global network to monitor coral reefs for change and expressed their interest in participation (IOC 1993).

Subsequent planning through the IOC, in coordination with ICRI, has shifted the emphasis of the GCRMN to provide a framework for a long-term monitoring system for coastal and near-shore observations of importance to understanding and mitigating threats to coral reefs and related ecosystems (Wilkinson in prep.). Thus the observations of the GCRMN must address critical issues of local to regional anthropogenic stress as well as global climatic change to provide information for sustainable use. The GCRMN will form a network of interacting agencies, institutions and people, incorporating existing programs to the extent possible. The network will:

- design and promote consistent monitoring protocols
- incorporate biological, physical, social, cultural and economic studies
- assist in developing infrastructure for monitoring
- assemble monitoring and research data on coral reefs into regional databases
- ensure that local users and managers are fully involved in the collection, analysis and interpretation; and prepare periodic reports of reef status.

While the number and location of sites has yet to be determined, it has been estimated that around 100-150 "extensive", low level sites will be needed for proper spatial coverage (LOIC2 1994). The fewer, higher technology, "intensive" sites are expected to either be located in, or fully supported by, developed nations with adequate resources, placing the burden on the developed nations and established marine laboratories to begin coordination to build these sites.

The GCRMN will develop strong regional nodes through which its national participants will cooperate. A regional structure will provide the greatest sharing of resources among neighboring countries and improve the focus of resources on those problems most pressing to reef health and sustainable use. Many of the intensive monitoring sites may serve as method development, data management and training centers for the regional nodes as well as sites for preparation and delivery of satellite remote-sensing and synthetic data summary products. The regional node should develop mechanisms through which costs are shared by regional participants, donors interested in the region and regional development banks.

Regional networks and related programs

The ASEAN-Australia Living Coastal Resources Project was conducted from 1986 to 1994 (Wilkinson 1994; English et al. 1994). Participating institutions from five ASEAN countries worked with Australian counterparts to perform standardized studies of marine ecosystems throughout the region. Its objectives were:

- to provide baseline information concerning representative coastal and continental shelf ecosystems for use in coastal zone management,
- to establish effective information exchange and a regional database, and
- to further develop scientific and technical expertise.

ASEAN-Australia participants carried out extensive surveys including 942 transects at 42 reef locations throughout the region. The final, consolidated database for the project is a resource of substantial value.

CARICOMP, the Caribbean Coastal Marine Productivity Program, was established in 1990 and consists of 25 sites in 16 countries that conduct a standardized, synoptic set of measurements of the structure, productivity, and associated physical parameters of relatively undisturbed coral reefs, seagrasses, and mangroves (Ogden et al. in press). Since 1993, approximately 12 sites have fully implemented the protocol, 7 sites are doing some part of it, and 6 sites are in the planning phase. The program is designed to determine the dominant influences on coastal productivity and to discriminate human disturbance from long-term natural variation in coastal systems. The network provides a rapid response capability for regional phenomena such as coral bleaching, mass mortalities and diseases, and periodic oceanographic phenomena and regularly organizes workshops and training sessions. To our knowledge the CARICOMP network is the only presently functioning international coastal marine monitoring program.

PACICOMP, the Pacific Coastal Marine Productivity Program, is planned as a counterpart to CARICOMP. An initial 4-year planning period is envisioned to organize and implement a cooperative program among tropical Pacific marine laboratories in the for standardized, long-term and systematic measurements of key environmental variables.

It is expected that the International Year of the Reef (IYOR) in 1997 will promote a major effort to assess the condition of coral reefs worldwide, document patterns of degradation and their causes, promote the sustainable management of reefs, and train reef managers (IYOR 1996a, 1996b). IYOR will provide a global context for national and regional efforts, and will promote collaboration and co-ordination between organizations pursuant to the ICRI goals. IYOR is implementing a scientific program to develop and test methods for the rapid assessment of coral reef ecosystems. Several scientists are performing initial assessments of reefs and making return visits to many reef sites, including the insular Pacific, Indonesia, Tanzania, the Philippines, the Bahamas and Puerto Rico, where work had been performed in previous years (IYOR 1996a).

The role of volunteer programs and organizations in data gathering is now considerable. Many of these are international in their scope and manage datasets covering information for hundreds of reefs. Such programs include Earthwatch, REEFWATCH, Coral Cay Conservation, Frontier, Raleigh International, CORAL WATCH Environmental Monitoring Program, R.E.E.F. Fish Survey Project, Project Reef Spawn, as well as a number of international training programs for non-professionals. A full review of these is provided in Wells (1995).

Regular reports

The GCRMN coordinator will facilitate the assembly of regional and global reports for presentation at international fora (Wilkinson in prep.). Regular updates should include presentation at each quadrennial ICRS of an overall summary and regional reports similar to those presented at the ICRI meeting and in this session of the 8th ICRS. This session of the 8th ICRS includes several regional reports and results of an anecdotal questionnaire sent to senior reef scientists. This will satisfy part of the reporting process for ICRI as specified in the ICRI *Framework for Action* (ICRI 1995). Additional reports will be produced by the GCRMN and ICRI as needed for various international and regional fora.

DATA SYSTEMS AND HYPOTHESIS TESTING

Databases and coral reef mapping

Information exchange is key to the assimilation of data for improved understanding at the national, regional and global levels. Several countries around the world have expressed an interest in developing national databases of coral reefs. Japan has a major database centered on aerial photographs of its coral reefs. Australia's Reef Ecology Database keeps track of research information on over 3,000 coral reefs. There are strong moves toward the development of regional and global databases as well (Table 1).

Additionally, the Australian Institute of Marine Science (AIMS) will provide database computing support for the anecdotal GCRMN questionnaire, and regional databases. The AIMS Long Term Monitoring (LTM) database contains monitoring records from 240 reefs in the Australasian region over 12 years, while AIMS helped establish the ASEAN-Australia database. AIMS LTM data are offered on-line to managers and will be the model for Regional Nodes. The database will be compatible with the ReefBase and FishBase databases at ICLARM, and those of WCMC in Cambridge.

Table 1: Regional to global databases relevant to coral reef research and management. Information from Wells (1994) and other sources as cited in the text.

Database	Sponsor	Contents
ReefBase	ICLARM	global coral reef data
Biodiversity Map Library	WCMC	global GIS on coral reefs and other marine life
FishBase	ICLARM	fish and fisheries, including coral reefs
Coral Reef Fish Biodiversity	IUCN	reef fish distribution maps
CoralBase	AIMS	coral taxonomy and biogeography
Protected Areas	WCMC	over 350 protected coral reef areas
Coral Fisheries Literature	UK-ODA	coral reef fisheries publications
Living Coastal Resources	ASEAN-Australia	coastal surveys
Coral Conservation	Nature Conservancy	western Atlantic coral distribution
CARICOMP	CARICOMP	coastal surveys and monitoring

ReefBase

Many of the data functions for ICRI and the GCRMN will be provided by the ReefBase project at ICLARM and the WCMC. ReefBase is a relational database for structured information on coral reefs and their resources that will serve as a computerized encyclopedia for use in reef management, conservation and research (McManus and Ablan in press). In collaboration with other international, regional and national databases, ReefBase provides a means of comparing and interpreting information at local to global levels. It will provide a library of analytical routines to make full use of the stored information and facilitate appropriate interpretation and synthesis, including Ecopath 3.0, an ecosystem modeling program. Various subsystems include the development of standards for gathering data on economic, social, cultural and other reef governance-related variables and systems to gather data on coral reef communities using volunteer diver programs and inexpensive global positioning system receivers. The World Conservation Monitoring Center (WCMC) collaborates in the project and is responsible for preparing a global coral reef geographic information system (GIS) gathering, preparing and harmonizing data from many sources.

Despite its early stage, ReefBase provided much of the material in the *State of the Reefs* report (Jameson et al. 1995). The database and its associated models, texts, and other databases are now being distributed on CD-ROM. The database currently includes over 6,000 coral reefs, 2,000 records of stresses affecting coral reefs, 800 records of fisheries and mariculture and 5,300 records of tourist use of reefs. It also includes a complete list of legally gazetted protected areas with coral reefs linked to the WCMC Protected Areas Database and 138 maps covering all known coral reefs in 108 countries or island states, summarized globally and in five regions. ReefBase can display these data geographically relative to various factors such as stresses, fisheries harvests and tourism uses.

Data dissemination

It is envisioned that all data collected through the GCRMN and related efforts will be broadly disseminated to the coral reef science and management communities. While ReefBase has been released on CD-ROM, the Internet and World Wide Web (WWW) are allowing databases to be updated continually with rapid, open information sharing and a set initial "publication" cost. Most importantly, users with access to Internet technology can rapidly update their datasets as desired for free or at minimal cost.

Many of the maps from WCMC are already available at the WCMC WWW site (<http://www.wcmc.org.uk>) together with full map references and other related data. The WCMC expects to expand the data holdings and products available under this system. Other mechanisms of information sharing are the WWW site (<http://coral.aoml.noaa.gov>) and the Coral-List mailing list (coral-list@reef.aoml.noaa.gov) maintained by the Coral Health and Monitoring Program (CHAMP). This program was established to provide information to improve coral reef health throughout the world. The WWW site provides near real-time data products derived from satellite images and monitoring stations at coral reef areas, a data repository for historical data collected from coral reef areas and a venue for the exchange of various information. The Coral-List has provided a network through which coral reef researchers and managers share information on coral reef issues and bring attention to developments in the field.

MONITORING AS A TOOL FOR MANAGEMENT

Information for accurately evaluating the condition of the world's reefs is critical for effective integrated coastal zone management. To be useful, monitoring programs must be designed with scientific and management questions in mind and their development and implementation must involve managers and user groups to the maximum extent practicable. A particular need is the ability to quickly and accurately assess the health

of ecosystems and the level of environmental threats. However, we must first develop an understanding of expected values and ranges for selected variables under natural conditions before we can use them to evaluate coral reef health. The programs described above will provide an increasingly accurate view of the changing state of ecological integrity of coral reefs in the face of global change. However, there are several areas in which further research at a well-coordinated, international level is needed:

- developing criteria and cost-effective procedures for the assessment of coral reef health and integrity – including remote-sensing based methods where possible;
- the strengthening of efforts to map the coral ecosystems of the world, with an emphasis on reefs not currently found on navigation charts;
- the further understanding of the consequences of reef degradation to people dependent upon them; and
- the investigation of potential effects of global climate change on the recruitment of reef organisms, particularly those on which coastal people are dependent for food and livelihood.

Wise coastal management in reef dependent communities becomes more important as human populations and their pressure on coastal ecosystems increases. According to Agenda 21, more than half of the world's population lives within 60 km of the shoreline and this could rise to 75% by the year 2020 (UNCED 1992). Unfortunately, most countries have not applied integrated coastal zone management practices, preventing the full blending of economic and environmental decision making into resource planning. However, the interactions between natural scientists, social scientists and managers are increasing. Through the process of adjusting management directions to changes in the status of resources and user groups, adaptive management may provide the functional interface needed to connect natural and social scientists with resource managers (IEM 1995). Under adaptive management, policy decisions are viewed as experiments subject to modification, rather than fixed and final rulings. With a thorough understanding of ecosystem health, the needs of dependent communities and human impacts, managers can adapt their approaches to sustain resource quality and way of life. The interest in describing and quantifying the dependence of humans on coral reefs is increasing and a variety of studies on social and economic aspects of coral reef fisheries have been summarized in a recent review (McManus 1996).

The participants of the ICRI Workshop (ICRI 1995) agreed that research and monitoring programs are needed to assess the status of coral reefs, to evaluate the success of management and conservation actions, and to develop more effective management practices. Future work must address the synergies between human effects and natural variations in light of modern and traditional uses for the resources. It is frequently said that we don't manage resources – we manage people. It is only through consideration of both resources and their users that we can ever determine the status of coral reef ecosystems.

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