



## Science and the management of coral reefs

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### ABSTRACT

Increasing accessibility of coral reefs from the latter third of the 20th century led quickly to recognition of the vulnerability of coral reef communities to a combination of direct and indirect human impacts. Coral reefs are confronted by the stark threats of climate and ocean changes from the increasing number, intensity and forms of human use impacting global and marine systems. Management, particularly of accessible coral reefs, occurs in the context of multiple scale transboundary water column linkages of lifecycle processes and increasing human use of coastal and marine space. Four decades of experience have demonstrated the combined importance of biophysical and socio-economic sciences and sharing knowledge with communities for developing implementing effective management. In the face of environmental and socio-economic change the challenge for science and management is to develop knowledge and management responses that can better understand and increase resilience to improve the outlook for coral reef communities.

### 1. Introduction

Coral reefs have been charismatic since 16th century mariners brought tales to Europe of travels through perilous waters to colourful coral gardens, plentiful fish and strange sea creatures. In the 18th and 19th century community and scientific interest in coral reefs grew with exotic specimen collections, illustrations and reports from voyages of trade, exploration and hydrographic survey. The logistic challenges for sustained research in remote tropical areas were substantial but the prospect of studies of marine environments very different from those of high latitude Atlantic coastal waters was enticing. Bowen (2015) identifies the Carnegie Institution of Washington 1913 Murray (Mer) Island studies in Torres Strait and the year-long Royal Society, Great Barrier Reef Committee Expedition of 1928–29 as the first sustained field laboratory and in situ studies of coral reefs.

Before external contact, local customary practice based on traditional knowledge provided for conservation of coral reefs and associated ecosystems. This was part of a management system with a common stake in sustaining marine food resources and related cultural values. Many of these practices were constrained or lost where colonisation brought a cultural clash between customary tenure and the western legal concept of freedom of the seas (Johannes, 1978). Increased accessibility and economic engagement brought the need to manage activities and impacts in areas with limited baseline data, limited surviving knowledge of customary management and no tradition of, or prior exposure to, biophysical research.

After World War 2 the newly available technologies of SCUBA

diving and underwater photography enabled direct survey, observation and experimental studies of coral reefs. Images and reports of field studies in the 1950's television series of Hans Hass and Jacques Cousteau brought the beauty of coral reefs to a wide audience and stimulated a growth of ecological research. The first permanent reef research stations were established at Coconut Island Hawaii in 1947, Heron Island in the southern Great Barrier Reef (GBR) in 1958, Discovery Bay Jamaica in 1965 and Panama in 1966 enabling sustained field and laboratory studies of local reefs accessible by small boats Bowen (2015).

The growth of coral reef science in the second half of the 20th century, brought studies of changes ranging from direct impacts of destructive human uses and severe natural events. The need for conservation of the biodiversity and natural resource sustainability of coral reef ecosystems was increasingly apparent. This occurred against the broader background consultative processes started in 1958 to develop and implement the Law of the Sea Convention (UN, 1982), the Convention on Biological Diversity (UN, 1992) and regional agreements for management of seas and fisheries.

The issues for coral reef science and management span jurisdictions and scales from locally accessible reefs with high human use to rarely visited remote island and archipelagic regions.

The Great Barrier Reef (GBR) has played a substantial role in knowledge sharing and development of international programs of coral reef research and management. This paper draws on that experience to provide a brief overview of the application of coral reef science in development of management for conservation and resource sustainability.

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## 2. The growth of scientific studies and coral reef management

From the 1960s coral reef research expanded rapidly thanks to the growing ease of travel from high latitude research centres to tropical coasts. The accessibility of complex biological communities in clear, warm shallow waters provided opportunities for substantial curiosity driven research. The first International Coral Reef Symposium (ICRS, 1962) was held in India in 1969 where 36 scientific papers were presented to a total of 72 participants mostly from the Indo-Pacific Region. Most of the papers reported descriptive surveys and studies of species distributions, diversity and taxonomy. Issues of management were not directly addressed but the symposium recommended taxonomic studies, not only of coral but of other members of reef biota as fundamentally necessary for understanding the ecology and physiology of coral reefs. A subsequent outcome was the establishment of an international working group outcome to:

1. Identify the major scientific problems in the quantitative ecology of coral reefs;
2. Evaluate and test existing methods for the quantitative description of abundance, composition and distribution of benthic invertebrate communities on reefs;
3. Recommend standard field techniques suitable for the problems identified under 1 above; and
4. Consider the need for a future symposium on the quantitative ecology and productivity of coral reefs.

This resulted in agreement on the need to support future ICRS as a regular forum for discussion and coordination of coral reef science. In 1974, a workshop at the Heron Island research station following ICRS 2 that led to the publication in 1978 of “Coral reefs: research methods” (UNESCO, 1978). In 1975, an IUCN conference on Marine Protected Areas recognised the importance of coral reefs in calling for the establishment of a well-monitored system of Marine Protected Areas (MPAs) representative of the world's marine ecosystems identifying coral reefs as ecosystems of particular vulnerability (IUCN, 1976).

In Australia in the 1960s two controversial issues raised concerns for the future management of issues affecting the GBR. Both illustrated a substantial need for science to understand the issues for an unprecedented scale of management for conservation and sustainable use of coral reef areas within a large marine ecoregion.

Observations of large populations of Crown-of-Thorns starfish causing locally severe coral mortality on reefs in the central Great Barrier Reef raised many questions (Barnes and Endean, 1964). These related to the normality and possible causes of population outbreaks; the consequences of death of coral cover; potential time for recovery; and the need for and feasibility of management response. An ad hoc Committee of the Australian Academy of Science considered the available, but limited, evidence concluding that while local mortality was severe it did not appear to represent a threat to the geological structure of the Great Barrier Reef (Walsh et al., 1970). This did not assuage public concerns and the Australian Commonwealth and Queensland governments established an Advisory Committee to oversee Research into the Crown-of thorns starfish (Australian Government, 1975; Kenchington, 1978).

A proposal to mine coral reefs for limestone and anticipation of expansion of fisheries and tourism were issues of growing contention but the issue of permits for oil drilling raised particular concern and led to the appointment in 1970 of a Royal Commission into petroleum drilling in the area of the Great Barrier Reef (Australian Government and Government of the State of Queensland, 1974). The Commission heard evidence from many of the leading global researchers on the extent, relevant gaps in, and management implications of, contemporary scientific knowledge of coral reefs. It found that limitations of research knowledge were such that its members were unable to agree on a recommendation on the question of whether there were any

localities wherein the effects of an oil or gas leak would cause so little detriment that drilling there for petroleum might be permitted”.

The Commission recommended that “a special statutory authority should be established responsible to the appropriate Parliament for ecological protection and the control of research and development within the Great Barrier Reef Province”. This was addressed in the passage of the Great Barrier Reef Marine Park Act (1975) to provide for conservation and reasonable use of the Great Barrier Reef Region. In 1976 the Great Barrier Reef Marine Park Authority (GBRMPA) was established with an expectation that the GBRMP would be established in about a decade.

Substantial investment in Great Barrier Reef research capacity included the establishment of the marine biology department at James Cook University in 1968; the Australian Institute of Marine Science in 1972; research stations at Lizard Island by the Australian Museum in 1978, at Orpheus Island by James Cook University in 1979; and expansion by the University of Queensland of facilities at the Heron Island Research Station.

At the same time in the Philippine archipelago, protection of coral reefs had become the subject of research because of falling fish stocks. A vicious cycle had emerged with growing human population, increasing fishing pressure, longer workdays for fishers that encouraged explosive, cyanide and other destructive fishing techniques that damaged coral reef habitats. The damage to coral reef habitats caused stocks to fall faster. A long term research and management program reviewed by (Alcala et al., 2005) was established in 1982 through close engagement and knowledge sharing with the local communities of the studied islands by researchers working at Silliman University. Management was through creation of, and sustained compliance with, marine reserves protecting coral reef habitat were initiated and demonstrated to increase fish stocks within and beyond reserve boundaries over two decades.

Similar local scale research and management initiatives for biodiversity conservation and food security in coastal and island coral reefs emerged in Indonesia, Pacific Islands, the Indian Ocean and East Africa are summarised in IUCN (2000).

## 3. The international context of coral reef management

At ICRS4 in Manila in 1981, UNESCO supported presentation of 50 papers to addressing resource management and environmental impact; a workshop on research and training priorities for coral reef management; and the subsequent publication of a coral reef management handbook (UNESCO, 1984).

A workshop on managing coastal and marine protected areas was held during the World Congress on National Parks in Bali Indonesia in 1982. This shared knowledge of widespread activity in coral reef conservation and resulted in the publication in 1984 of the first edition of the IUCN guide for planners and managers of marine and coastal protected areas. This was subsequently updated to a third edition (IUCN, 2000).

The UNEP Regional Seas program developed between 1976 and 1985 to support coordination and development of environmental management in the coral reef regions of the Caribbean, West Africa, the Red Sea and Gulf of Aden, Arabian Gulf, Gulf of Oman and South Asia, East Asian Seas and the Pacific Ocean. In 1987 an edited volume synthesized and updated knowledge of human impacts on coral reefs (Salvat, 1987) and the UN “Brundtland Commission” Report on Sustainable Development (UN, 1987) identified coral reefs as vulnerable marine ecosystems with high levels of human dependency.

The 1992 UN Rio Summit on Sustainable Development adopted Agenda 21 (UN, 1992) in which Chapter 17 addressed: “Protection of the Oceans, All Kinds of Seas, including Enclosed and Semi-enclosed Seas, and Coastal Areas and the Protection, Rational Use and Development of their Living Resources.” In the follow-up to the Rio Summit, small island developing nations raised management of their coral reefs

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