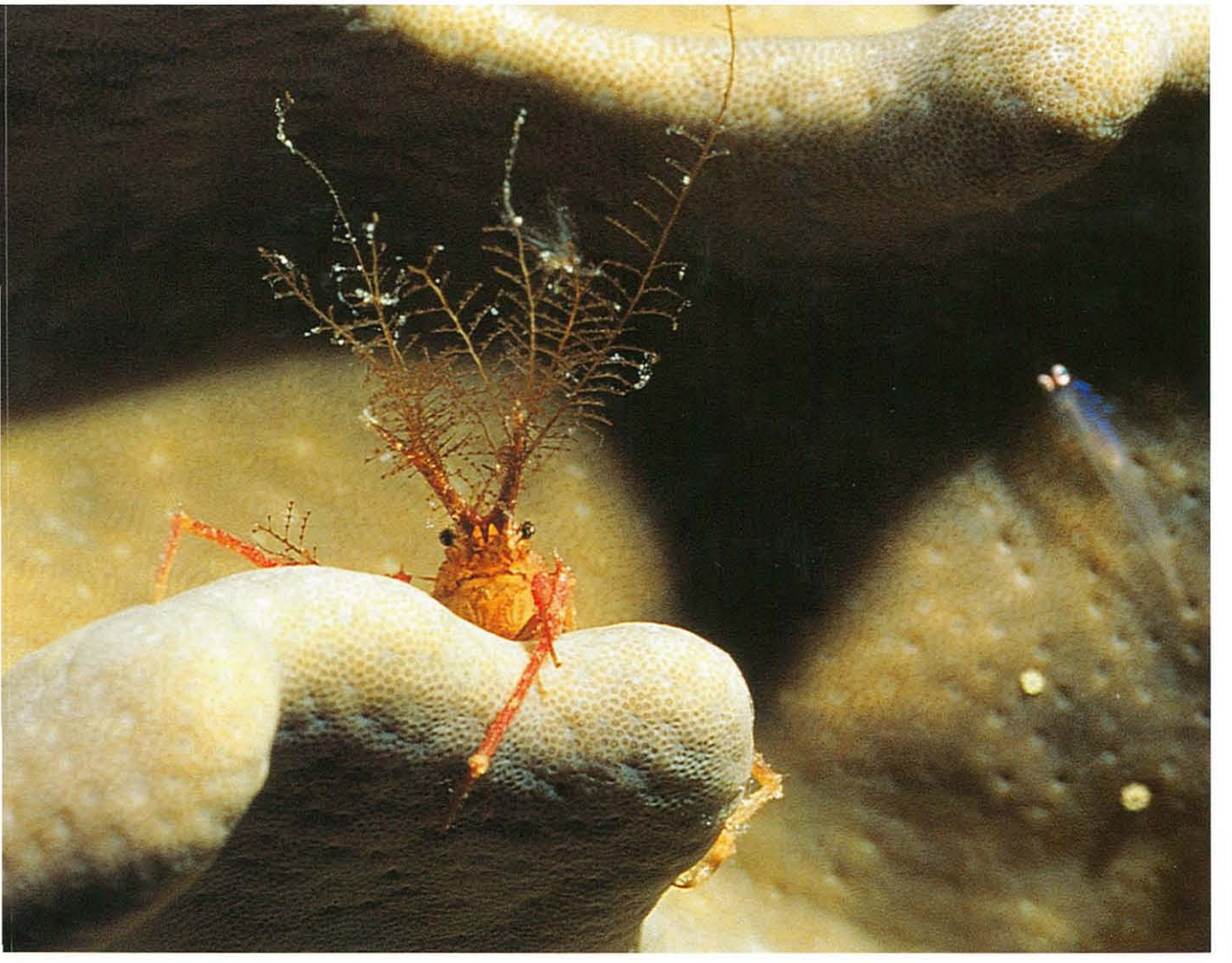
State of the Great Barrier Reef World Heritage Area 1998



GREAT BARRIER REEF
MARINE PARK AUTHORITY

State of the Great Barrier Reef World Heritage Area 1998

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Cover Image: Spider crab on coral
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Foreword

The Great Barrier Reef World Heritage Area is the largest in the world and one of just a few World Heritage Areas which meet all four natural World Heritage criteria. It was inscribed on the World Heritage List in 1981. Although originally seen as a prize or badge of honour, World Heritage status is now increasingly being seen as an international obligation to maintain an area of world importance in a condition which will enable future generations to appreciate its unique features. An important component of our responsibilities under the World Heritage Convention is to report at intervals on the status of the World Heritage Areas under our stewardship. Consequently, the Great Barrier Reef Marine Park Authority has produced the *State of the Great Barrier Reef World Heritage Area 1998*.

This report is the first ever attempt to synthesise information on the state of the environment, human pressures on the environment and management responses to those pressures for the whole World Heritage Area. It represents an important step forward in our understanding of how humans affect the natural environment of the World Heritage Area and what we can do to minimise those effects. This report will also provide a guide to where we should be going in the future in order to ensure the Great Barrier Reef World Heritage Area keeps its status as the premier natural World Heritage Area.

In general I believe that this report allows us to be cautiously optimistic about the state of the Great Barrier Reef World Heritage Area. Although there are some organisms and environmental attributes which require further monitoring or even management action to address human impacts, virtually all of these potential problems are currently being addressed by one or more of the management agencies responsible for the care of the World Heritage Area.

Many of the reported attributes of the Area are not exhibiting indications of any major decline which is clearly attributable to human activity. However, lack of any evidence of a problem does not necessarily mean that everything is fine. Ongoing monitoring and careful management of potential impacts will be required in order to ensure the continued health of the World Heritage Area.

I am confident that in the future reports and updates to this document, I will be able to justify this optimistic outlook, and report on substantial progress in achieving proven sustainability for all human activities within the Great Barrier Reef World Heritage Area.

Ian McPhail

Chairperson

Great Barrier Reef Marine Park Authority

Contents

Summary

The distribution and abundance of most major environmental attributes in the Great Barrier Reef World Heritage Area are fairly well known, although comprehensive species distributions are lacking for many plants and animals. Out of 12 categories used for reporting in this document, all have had extensive surveys conducted for at least part of the environmental attribute on at least one occasion. However, significant areas of uncertainty regarding basic distribution and abundance remain for many groups of organisms including macroalgae, soft corals, inter-reefal and lagoonal benthos, sea snakes and inshore dolphins.

A smaller proportion of the environmental attributes have dedicated monitoring programs that are providing increasingly valuable trend data. Together with information on patterns of human activities and impacts, these long-term records allow us to determine whether the environmental attribute is being adversely impacted by human activities, and thus whether any management action is needed. Because virtually all environmental attributes vary naturally over time, long time-series are required before definite indications of human impact can be demonstrated. As a result, for most environmental attributes, it is not possible to say with certainty if they are in a satisfactory or unsatisfactory condition.

Despite this uncertainty, the lack of any major declines and uncontrolled human pressures permits a cautiously optimistic conclusion for environmental attributes such as corals, reef fishes, seagrasses, mangroves and island plants. On the other hand, whilst there are no major adverse trends evident for water quality, macroalgae and seabirds, lack of good trend data or the presence of substantial ongoing pressures mean that the outlook is less certain, and that continued vigilance and management action are needed. The crown-of-thorns starfish presents a dilemma to managers. While a third outbreak is currently developing in the Cairns to Cooktown region, the need for widespread management action is uncertain due to ongoing uncertainty regarding the role of human impacts as causal agents. Finally, there are some categories for which the trends are not encouraging and management action is required. They include dugongs south of Cooktown, at least three species of marine turtles, and lagoonal benthos in particularly heavily trawled areas. Appropriate management action has been identified in each of these cases, and in most cases implementation has commenced.

Generally, most issues of potential human impact on the Great Barrier Reef World Heritage Area have been identified, and management programs have been established by the Great Barrier Reef Marine Park Authority or other government agencies to ameliorate these impacts. Within the Great Barrier Reef Marine Park Authority, special programs exist to deal with Fisheries, Tourism, Shipping, Water Quality and Coastal Development, Indigenous Issues, and Threatened Species.

Although this report indicates numerous areas where further work is still required, it also demonstrates the breadth and depth of management commitment to the Great Barrier Reef World Heritage Area undertaken by the Commonwealth and Queensland Governments. In the context of other World Heritage Areas and other major coral reef systems, the Great Barrier Reef World Heritage Area compares very favourably in terms of general condition and management response.

The summary on the next two pages provides an indication of the current status of the various environmental attributes.

TABLE 1 Summary of major environmental attributes on the Great Barrier Reef

Attribute	State	Pressure	Response
Water Quality	• status fairly well known • limited trend data but no obvious adverse trends	• adjacent land use and associated nutrient and sediment run-off during flood events • loss of freshwater wetlands	• direct inputs of pollutants prohibited or strictly regulated • collaborative arrangements with State Government agencies being developed to reduce indirect inputs through run-off • comprehensive research and monitoring programs in place
Mangroves	• status well known • some medium-term trend data available • no obvious adverse trends	• principal pressure is clearing for coastal development	• mangroves protected by legislation from damage and removal • further work on cumulative impacts needed
Island Plants	• status fairly well known • no information on trends	• historical impacts from plant intoductions and grazing, some ongoing	• plants on most islands protected from direct damage or removal • ongoing monitoring needed
Seagrasses	• status fairly well known • some information on trends • no obvious adverse trends	• some potential pressures from coastal run-off and trawling, but few major impacts documented	• trawling prohibited by Marine Park zoning plans in nearly half of mapped seagrass area • trawling prohibited in additional areas by coastal strip closures • offshore beds less protected but impacts not documented
Macroalgae	• status poorly known • no information on trends • anecdotal reports of increased abundance due to human impacts	• potential impacts on nearshore algae from increased nutrients in run-off	• status information being collected • management needs uncertain • trend monitoring needed
Corals	• status fairly well known • no evidence of any major declines directly attributed to human impacts • some recent disturbances from crown-of-thorns starfish and bleaching	• potential pressure on inshore corals from increased sediments and nutrients in run-off, but no major impacts documented	• comprehensive research and monitoring programs in place • most major direct pressures regulated or prohibited
Crown-of-thorns Starfish	• status fairly well known • current outbreak in northern Great Barrier Reef • cause of outbreaks uncertain	• role of human activities in causing outbreaks is uncertain	• comprehensive research and monitoring programs in place • control measure developed for significant sites • need for further action not clear given uncertainty over causal factors
Fishes	• status of commercial species and common reef fishes fairly well known • no evidence of any major declines caused by human activities	• commercial, recreational and indigenous fishers • heavy fishing pressure in some areas	• comprehensive research and monitoring programs in place • variety of management measures to restrict and regulate fishing effort

Attribute	State	Pressure	Response
Birds	• status fairly well known • trends known for some sites where some species have declined	• human disturbance from visitation • habitat loss and deterioration	• some sensitive nesting sites closed to visitors • research and monitoring programs in place at some sites • more information needed on status for many areas • need for further action uncertain due to lack of trend data
Marine Turtles	• status well known for two species • significant decline for one species, indications of decline for two others and no indication of decline for a fourth • no information on status of two other species, but both rarely seen	• bycatch in trawl and shark nets • hunting, both locally and overseas • predation of eggs and young by feral animals • habitat removal and disturbance	• important nesting sites protected • efforts under way to reduce bycatch in trawls • need for international agreement to protect turtles • ongoing monitoring
Sea Snakes	• status information needed	• bycatch in trawl nets	• management requirements uncertain • processing of sea snake skins no longer allowed
Dugongs	• status and trends fairly well known • decline in southern Great Barrier Reef population	• bycatch in mesh and shark nets • boat strike • indigenous hunting	• Dugong Protection Areas established • voluntary cessation of traditional hunting by most indigenous communities south of Cooktown • traditional hunting south of Cooktown no longer permitted • comprehensive research and monitoring programs in place
Whales and Dolphins	• status and trends for humpback whale fairly well known • no information on other whales or dolphins, but inshore species possibly in decline	• whale watching of baleen whales, particularly humpback and dwarf minke • inshore dolphins caught as bycatch in mesh nets	• whale-watching guidelines developed • monitoring and protection measures for inshore dolphins needed
Inter-reefal and Lagoonal Benthos	• status poorly known • likely substantial impacts in areas of high intensity trawling	• trawling • nearshore communities potentially affected by increased sediments and nutrients in run-off	• some progress towards understanding responses and recovery • trawling prohibited by Marine Park zoning plans in over half of inter-reefal area and about 10% of lagoonal area • management plans being developed which aim to reduce fishing effort


145°E
PAPUA NEW GUINEA
150°E
Port Moresby
10°S
Thursday Island
10°41'S 145°00'E
Bamaga
FAR NORTHERN SECTION
(Area: 85 050 sq km)
Lockhart River
13°00'S 145°00'E
GREAT BARRIER REEF
Great Barrier Reef World Heritage Area
(Area: 347 800 sq km)
Great Barrier Reef Marine Park
(Area: 339 750 sq km)
15°S
15°00'S 146°00'E
Cooktown
CAIRNS SECTION
(Area: 35 500 sq km)
CORAL SEA
Port Douglas
Cairns
Innisfail
17°30'S 147°00'E
Tully
CENTRAL SECTION
(Area: 75 850 sq km)
Ingham
Townsville
Ayr
20°S
Bowen
Proserpine
21°00'S 152°55'E
Mackay
QUEENSLAND
GUMOO WOOJABUDDEE SECTION
(Area: 350 sq km)
MACKAY / CAPRICORN SECTION
(Area: 143 000 sq km)
Tropic of Capricorn (23°26.5'S)
Yeppoon
Rockhampton
Gladstone
25°S
24°30'S 154°00'E
Bundaberg
Hervey Bay
N
0 100 200 300 400
Kilometres
Nambour
BRISBANE
Map No. C034/98
145°E
150°E

Introduction

THE GREAT BARRIER REEF WORLD HERITAGE AREA

The Great Barrier Reef World Heritage Area is the largest of the world's 552 World Heritage Areas, covering 347 800 km² and stretching for over 2000 km along the north-eastern coast of Australia. It is larger than the states of Victoria and Tasmania combined.

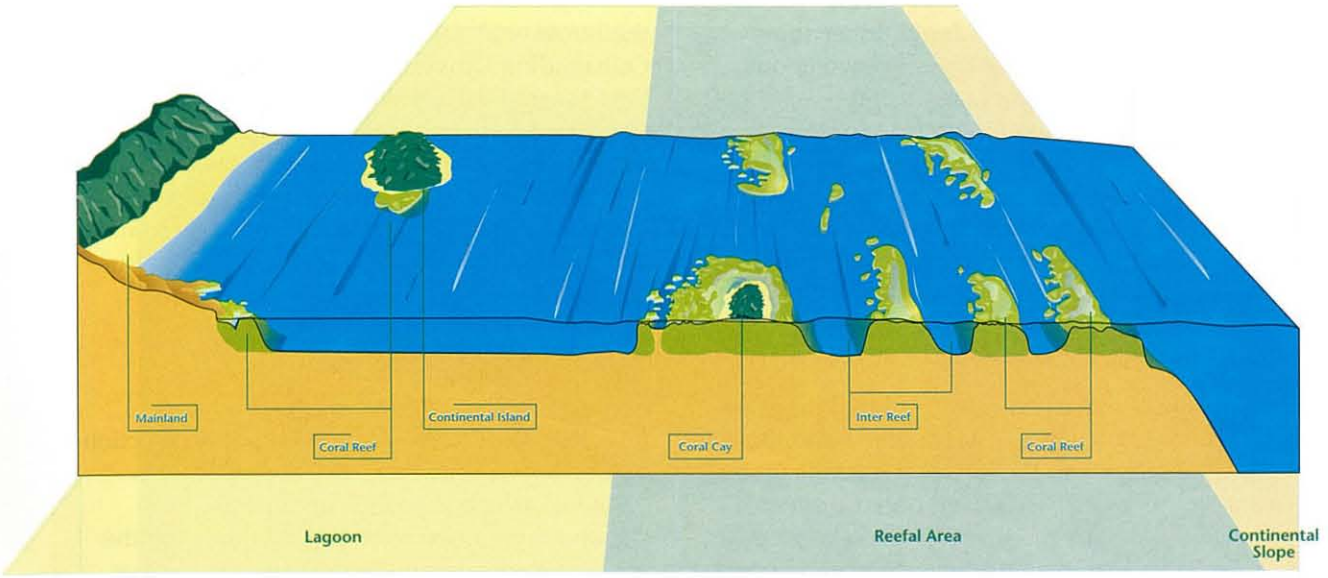
For many people, the Great Barrier Reef constitutes a complex maze of coral reefs. While the World Heritage Area does indeed contain over 2800 coral reefs, these reefs account for only about 6% of the Great Barrier Reef World Heritage Area. The other main geographical components of the World Heritage Area are the continental slope (36%), the inter-reefal areas (25%) and the Great Barrier Reef lagoon (33%). Whilst most reefs occur in the reefal region, approximately 6% of the total area of coral reefs occurs within the Great Barrier Reef lagoon (mainly fringing reefs or small patch reefs). This report focuses almost exclusively on the reefal (including reefs and inter-reefal areas) and lagoonal portions of the Great Barrier Reef World Heritage Area. Although almost nothing is known of the biology or ecology of the continental slope area, at this time there is comparatively little direct human use of the area and probably very few direct human impacts.

Of the more than 2800 catalogued reefs in the Great Barrier Reef World Heritage Area approximately 20% are submerged reefs or shoals, while about 26% are fringing reefs around continental islands or along the mainland coast. The remaining reefs are typical shelf reef platforms of various shapes and sizes. The shelf on which these reefs lie, varies in width from over 200 km south of Mackay to less than 50 km along much of the north coast from Cairns to Cape Weymouth. Water depths in the lagoonal area are typically 20–30 m, increasing to 40–60 m between reefs on the outer shelf.

The climate of the Great Barrier Reef World Heritage Area is influenced by monsoonal wind and rainfall patterns. Strong south-easterly winds dominate during the dry winter months, while weaker variable winds are more likely during the summer wet season when most of the annual rainfall occurs. This seasonality is more pronounced in the central and northern thirds of the reef. Air and sea temperatures also show considerable seasonal variation, although this seasonal variation is reduced in the northern and offshore regions. Mean sea temperatures on offshore reefs vary between about 23°C in July–August and 28°C in January–February while inshore areas generally experience a higher seasonal range (21°–30°C).

Ocean currents and tides are important physical processes which can profoundly affect the distribution and status of organisms in the World Heritage Area. At a regional scale, the two most important currents influencing the Great Barrier Reef are derived from a bifurcation of the westward flowing South Equatorial Current in the Coral Sea at about 14° south. The northern arm of this bifurcation is called the Hiri Current and the southern arm is the East Australian Current. Variations in the location of the bifurcation can have a profound influence on current directions along and over the shelf with northward shelf-edge currents occasionally occurring as far south as Myrmidon Reef off Townsville. Fluctuations in the intensity of these shelf-edge currents are also important as they can induce upwelling of deep nutrient-rich water onto the shelf and around the reefs. The East Australian Current appears to have an influence across the shelf inducing net southerly flows in the central lagoon. However, this can be substantially modified or even reversed during periods of high winds, especially in shallow coastal areas during the south-east trade winds, when northward flows are quite common. Within the reef matrix, current flows are much more complex as a result of the interaction of tides, currents and reef shape. In areas where reefs are closely spaced together, there is a significant blocking effect which isolates lagoonal water from the shelf-edge flows. In general, water exchange between the lagoonal and reefal regions is restricted, although coastal headlands can create cross-shelf flows in some areas. Tides within the Great Barrier Reef World Heritage Area superimpose a 12-hourly oscillatory flow on top of these currents. This oscillation is oriented primarily in a cross-shelf direction in most areas and is strongest in areas of highest tidal amplitude near Broad Sound.

The marine elements of the Great Barrier Reef World Heritage Area can be divided into three major biophysical environments: the lagoon, the reefal area and the continental slope.



The Great Barrier Reef was first provided with comprehensive protection in 1975 through the passage of the Great Barrier Reef Marine Park Act. This Act established the Great Barrier Reef Region, within which sections of the Great Barrier Reef Marine Park could be declared. With the exception of a few coastal areas most (over 98%) of the Region is now declared as Marine Park. The Act specifically prohibits drilling and mining for minerals within all areas of the Marine Park.

The Great Barrier Reef World Heritage Area was inscribed on the World Heritage List in 1981 in recognition of its outstanding universal value. It is one of only a few World Heritage Areas listed for all four World Heritage criteria for natural heritage. Thus it is 1) an outstanding example representing the major stages in the earth's evolutionary history; 2) an outstanding example representing significant ongoing ecological and biological processes; 3) an example of superlative natural phenomena; and 4) contains important and significant habitats for in situ conservation of biological diversity.

The boundary of the World Heritage Area is nearly identical to that of the Great Barrier Reef Region, with the exception that the Region does not include state owned islands or internal waters of Queensland. Thus some parts of World Heritage Area (a little over 2%) are not within the Region or declared as Marine Park. Some of these areas (most state islands and some coastal areas) are protected under State National Parks or Marine Parks legislation. In addition, under a memorandum of understanding, the Great Barrier Reef Marine Park Authority acts as a lead agency for the Commonwealth for matters relating to the Great Barrier Reef World Heritage Area.

THIS REPORT

The *State of the Great Barrier Reef World Heritage Area 1998* represents the first ever attempt to synthesise information on the state of the whole World Heritage Area as well as human pressures on the environment and management responses to those pressures.

State of the environment reporting is an important part of environmental management. Although there have been a number of long-standing and quite comprehensive scientific monitoring and assessment programs on the Great Barrier Reef, the results of many of these programs have never been summarised in a management context, and no overall summary of all of these programs has ever been attempted. The *State of the Great Barrier Reef World Heritage Area 1998* is the first step in filling that gap.

In this report, emphasis is placed on summarising information from long-term, large-scale monitoring and research programs, including physical, chemical, biological and socioeconomic information. The implications of this information for management of the World Heritage Area are also discussed.

This report is intended to provide managers, policy makers and Reef stakeholders with an informative and readable summary of the status of the World Heritage Area. It also fulfils the obligations of the Great Barrier Reef Marine Park Authority to report to the World Heritage Committee of the United Nations Educational Scientific and Cultural Organisation (UNESCO).

This report is divided into two major sections: *Environmental Status* and *Management Status*. *Environmental Status* examines individual environmental attributes of the World Heritage

Area. Each attribute is considered under three headings. *State* describes what is known about the state of the environmental attribute. This includes information on long-term trends, where they are known. *Pressure* describes the pressures placed on the natural environment by human activities. *Response* describes management responses to minimise or remove those human pressures. This includes both a description of existing management responses and discussion of possible future ones.

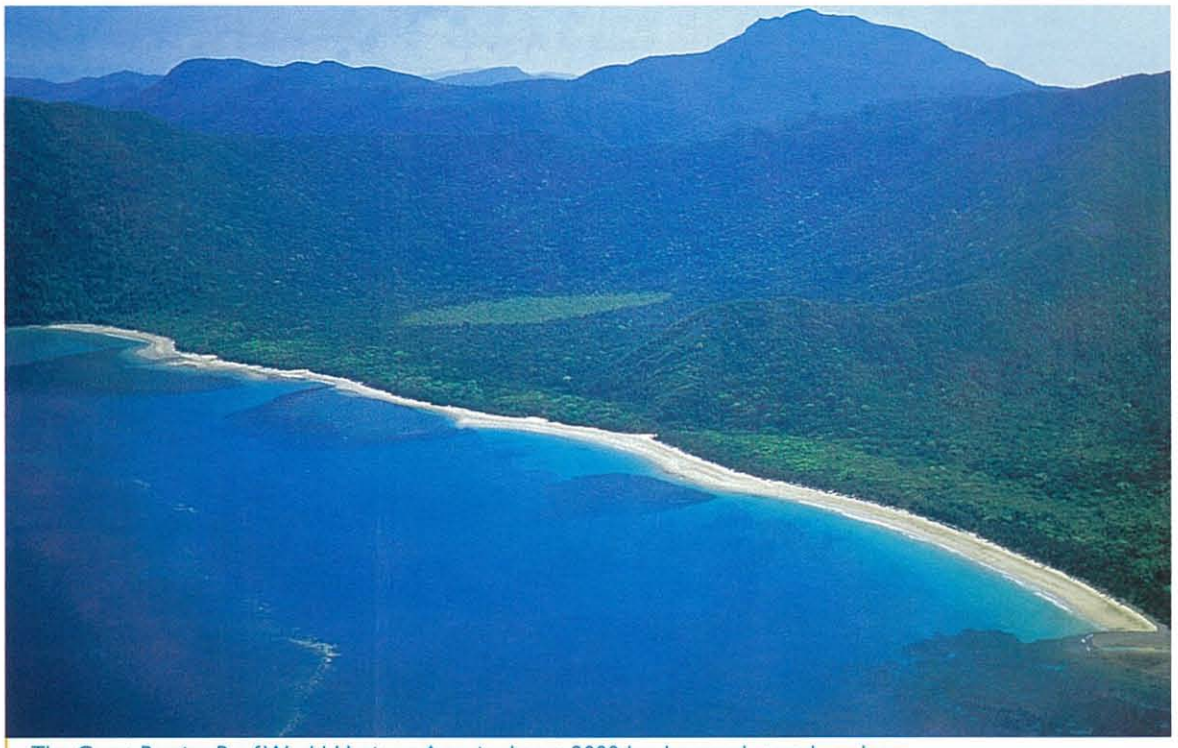
Management Status examines individual issues of significance to management. In some ways this leads to overlap with the *Response* sections under *Environmental Status*. However, because some management issues (such as *Monitoring, Tourism* and *Fisheries*) span many different environmental attributes, they warrant their own synthesised section. The first step in the production of this report was in November 1995 when the State of the Great Barrier Reef World Heritage Area Workshop was held. Researchers from a wide variety of fields presented summaries of information about environmental status and commented on their management significance. Managers also presented papers at the Workshop to summarise information about management activities. Papers from this workshop were published in the *State of the Great Barrier Reef World Heritage Area Workshop* proceedings and formed the main source of material from which this report was produced. In order to ensure that the information in this report is up to date, additional material published since the Workshop has also been incorporated. In particular, the Great Barrier Reef Conference on Science, Use and Management held in 1996, and the Lucas et al. report from 1998 on the Outstanding Universal Value of the Great Barrier Reef World Heritage Area have been used as important sources of recent information. All published source material used in the production of this report is listed in the Bibliography the intent is to provide easy access to more detailed and technical information than is contained in this report.

In order to further ensure the accuracy and currency of information in this report, an extensive review process was carried out. Initially, scientific experts reviewed each section of Environmental Status and the report was edited to incorporate their comments. Then stakeholder groups were invited to review the text and their comments were used to further improve the report. While further improvements and additions identified by some reviewers are planned for future reports, the input from all reviews greatly improved the quality of this document.

In producing this report, it was not intended to summarise or identify everything that is known about the World Heritage Area and its inhabitants. The focus has been on the status of the major environmental attributes, rather than producing a treatise on everything that is known about the ecology of the area. As a consequence, some high quality scientific research has not been directly cited in this report, either because it does not contain status information, or because it is summarised in a review paper which is cited. More detailed information can be found in the publications listed in the Bibliography. These publications were the sources for almost all of the information contained in the report. Only small amounts of unpublished information are included, typically very recent information that was supplied during the review process.

In general, this report focuses on habitats and species that are affected by human activities. From a management perspective, it is those environmental attributes which are subject to human pressures that require attention and action. As

The Great Barrier Reef World Heritage Area contains over 2800 coral reefs.



The Great Barrier Reef World Heritage Area is almost 2000 km long and stretches along the north-east coast of Australia.

an example, the section on fishes concentrates on species or groups of fishes that are exploited by humans, thereby focusing attention on a small fraction of the total fish biodiversity of the Great Barrier Reef World Heritage Area. In contrast, the section on marine turtles deals with all species of turtles found in the World Heritage Area because all are subject to human pressures. Some large and ecologically important groups of animals are not mentioned at all because there is only limited information on their status and they are not subject to direct, significant human pressure. Examples of such groups are sponges and sea squirts.

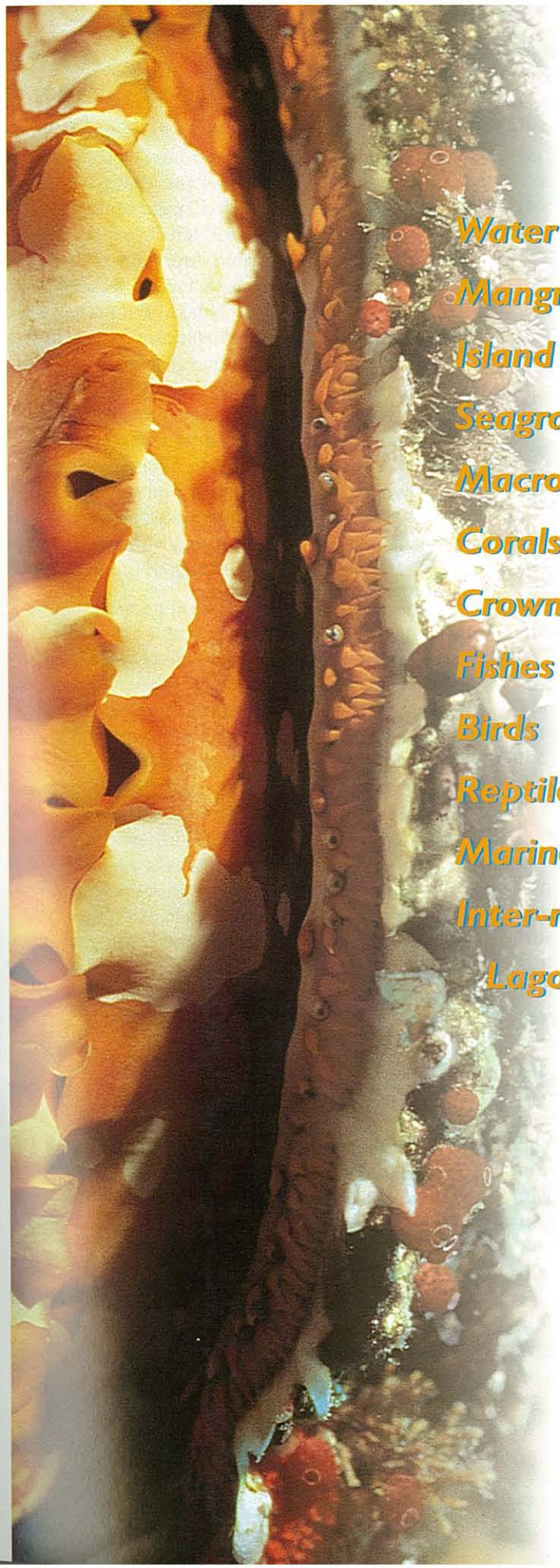
FUTURE DIRECTIONS

This report represents the first ever attempt to bring together information on biological status, human activities and management measures for the entire Great Barrier Reef World Heritage Area. While the Authority believes that the *State of the Great Barrier Reef World Heritage Area 1998* represents an important step forward in our understanding of the Great Barrier Reef and the issues affecting it, we are already aware of shortcomings in this report. Some environmental attributes are not adequately dealt with. Three examples are island plants and animals, crustaceans (such as mud and sand crabs) and sharks. Each of these environmental attributes is subject to significant human pressure and warrants further attention in updates to this report. In terms of human pressures on the World Heritage Area, we have not adequately dealt with sea dumping of dredge material or ports. Some ports cover areas that overlap with the World Heritage Area.

In the short term, these shortcomings will be addressed through the production of regular updates to the report. These updates will both fill gaps in the existing report and provide more up-to-date information as it becomes available. In five years' time the second edition of the report will be published: *State of the Great Barrier Reef World Heritage Area 2003*.

Before the production of the next report, the Great Barrier Reef Marine Park Authority will develop the concept of 'environmental status and performance indicators' for the Great Barrier Reef World Heritage Area. The indicators will include environmental parameters and measures of human use developed specifically to provide information to help improve management. The prime function of these indicators will be to allow informed judgement of the success or otherwise of management strategies in minimising the impacts of human pressures on the state of the environment. Unsuccessful management strategies can then be improved and successful ones can be identified and repeated.

Environmental Status



Water Quality

Mangroves

Island Plants

Seagrasses

Macroalgae

Corals

Crown-of-thorns Starfish

Fishes

Birds

Reptiles

Marine Mammals

Inter-reefal and Lagoonal Benthos

STATE

Determinants of Water Quality

A limited number of processes affect water quality in the Great Barrier Reef system by introducing substances which alter the system. These include rainfall, terrestrial run-off, Coral Sea upwelling, Coral Sea surface water exchange, nitrogen fixation and internal recycling. In the central Great Barrier Reef, where sufficient information is available to make quantitative estimates, terrestrial run-off of nutrients provides approximately 46% and 59 % of the 'new' nitrogen and phosphorus inputs respectively to shelf waters from external sources. Terrestrial nutrient inputs enter a shallow nearshore area comprising a small percentage (less than 10%) of total shelf area and water volume. This area supports coral assemblages and extensive seagrass meadows as diverse as reefs in clear-water offshore habitats.

Nitrogen fixation is an important source of nitrogen to the nutrient budget of the Great Barrier Reef system. Planktonic cyanobacteria, in particular *Trichodesmium* spp., are present in large quantities throughout the year and may provide 50% of the new nitrogen input to the central shelf. However, as both *Trichodesmium* biomass and fixation rates are not well quantified the budget estimates are subject to a high degree of uncertainty. Benthic cyanobacteria, particularly in reefal areas, also contribute significant nitrogen fixation inputs to the system. This contribution has been estimated to be approximately 5% of the new nitrogen input. Overall, however, Great Barrier Reef ecosystems derive most of their nutrient supply from internal recycling processes.

River Discharge

The coastal region adjoining the World Heritage Area is divided into a diverse range of wet and dry tropical catchments (the total area henceforth designated the Great Barrier Reef catchment). Most are small (less than 10 000 km^2), but two, the Burdekin (133 000 km^2) and Fitzroy (143 000 km^2) rivers are among the largest along Australia's eastern coast. Flows of water in all catchments bordering the World Heritage Area are highly variable, both between and within years. Discharge is dominated by large flood events associated with tropical cyclones and monsoonal rainfall. While the Burdekin and Fitzroy rivers have the greatest average flows (with their large dry catchments), significant flood events only occur episodically at intervals ranging between several years and a decade. An average of 60 km^3 of water is discharged yearly from the Great Barrier Reef catchment. Area-specific erosion is higher in the 'wet' catchments of the central Great Barrier Reef (16–18° south), but overall sediment and nutrient inputs are dominated by the large dry catchments as a consequence of larger average areas and water flows.

The principal sources of sediment and nutrients from the coastal catchments have been quantified. It is estimated that 23 000 000 tonnes of sediment, 77 000 tonnes of nitrogen and 11 000 tonnes of phosphorus are exported to the inshore coastal waters of the Great Barrier Reef. Sediment and nutrient delivery to Great Barrier Reef waters from terrestrial discharge has increased by four times in the 130 years since European settlement of the adjacent coast.

Sediment Resuspension

The south-easterly trade wind regime, which predominates for much of the year throughout the Great Barrier Reef, is capable of resuspending large masses of sediments in the shallow water of the inner shelf. Suspended sediment concentrations of up to 50 mg/L in the upper water column and 200 mg/L near the bottom are common in areas such as Cleveland and Halifax bays under these conditions. Nutrient release from suspended sediments in these events stimulates phytoplankton growth in the following days when chlorophyll concentrations may reach 1.5 µg/L compared to background concentrations of 0.4 µg/L. The release of nutrients from the sediments and from the water between grains of sediment contributes significant nutrient inputs in inshore waters. Sediment resuspension and the coastal northward current flow are the principal mechanism for the northward and shoreward transport of sediment along the Great Barrier Reef. In cyclonic wind conditions very large masses of sediment are resuspended and moved. The nutrients released following these events stimulate phytoplankton blooms in shelf waters with chlorophyll concentrations reaching 18 µg/L.

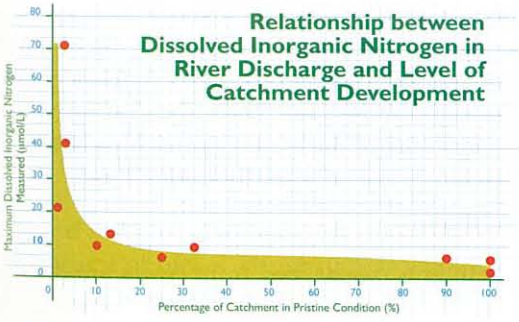

GREAT BARRIER REEF
WORLD HERITAGE AREA
Adjacent River Catchments
World Heritage Area boundary
River catchment area
145°E
150°E
PAPUA
NEW
GUINEA
Port Moresby
10°S
15°S
20°S
25°S
Thursday Island
Jacky Jacky
Olive–Pascoe
Lockhart
Stewart
Jeannie
Normanby
Endeavour
Daintree
CORAL SEA
Mossman
Cairns
Barron
Russell–Mulgrave
Johnstone
Herbert
Tully
Murray
Hinchinbrook Island
Black
Ross
Townsville
Haughton
Proserpine
Whitsunday Islands
Don
O'Connell
Burdekin
Mackay
Pioneer
QUEENSLAND
Plane
Styx
Shoalwater
Water Park
Curtis Island
Boyne
Tropic of Capricorn (23°26.5'S)
Rockhampton
Calliope
Baffle
Kolan
Fitzroy
Burrum
Bundaberg
Fraser Island
Burnett
Mary
Noosa
0 100 200 300
Kilometres
N
BRISBANE
Map No. C050/98

Chlorophyll and Nutrient Status

Rivers

Rivers entering the Great Barrier Reef carry their highest concentrations of dissolved and suspended materials during monsoon flood flow. As this is also the period of peak discharge, almost the complete load of materials entering Great Barrier Reef waters occurs during these short periods. Concentrations of suspended sediments reach 7000 mg/L in the Burdekin River and 1500 mg/L in the wet tropics rivers in peak discharge compared to values of 10 mg/L in non-flood conditions. Nutrient species also reach concentrations from two to ten times their non-flood values at such times. Concentrations at these times far exceed Australian and New Zealand Environment and Conservation Council guidelines for ecosystem health for some parameters while non-flood values are normally well within the guidelines.

Evidence for the changes in concentration of suspended sediment and nutrients caused by catchment development can be seen when rivers with varying levels and types of catchment land use are compared. The Jardine River which flows into the far northern Great Barrier Reef, is almost completely undeveloped and concentrations of dissolved inorganic nitrogen in wet season flow conditions are considerably smaller than the concentrations in rivers with catchments with substantial development for grazing (e.g. the Burdekin) or sugarcane cultivation (e.g. the Johnstone and Tully).



For ten of the catchments adjacent to the Great Barrier Reef World Heritage Area the amount of dissolved inorganic nitrogen that is discharged through rivers during the wet season depends on the percentage of the catchment that is in pristine condition.

Great Barrier Reef waters in non-flood conditions

Away from discrete sources of nutrients and sediments such as river mouths and sewage outfalls, patches of water with high concentrations of sediments, nutrients and chlorophyll appear to be rare and ephemeral.

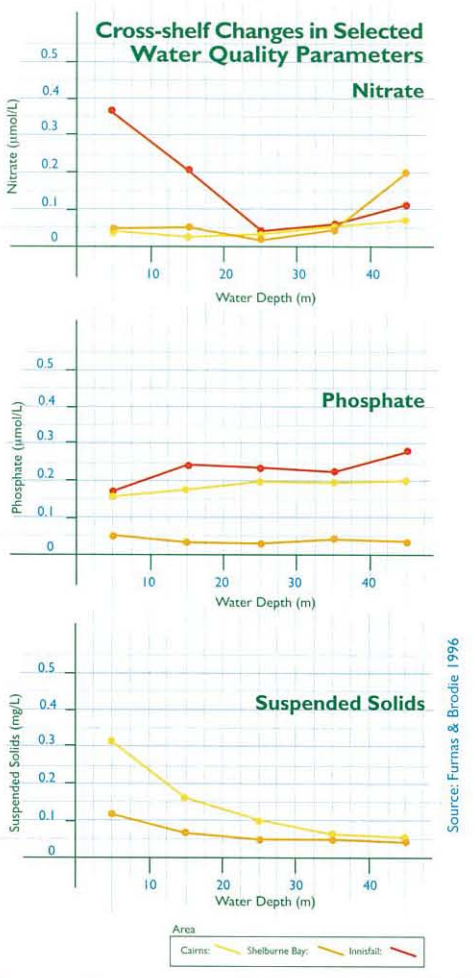
After major events such as cyclones and floods, elevated nutrient concentrations usually disappear within a few weeks.

Latitudinal trends

Most nutrient species show significant variations with latitude. Minimum concentrations of almost all measured constituents are observed in far northern Great Barrier Reef waters. Maximum concentrations of a number of nutrient species are found in the Torres Strait area, the central Great Barrier Reef, or both.

Cross-shelf trends

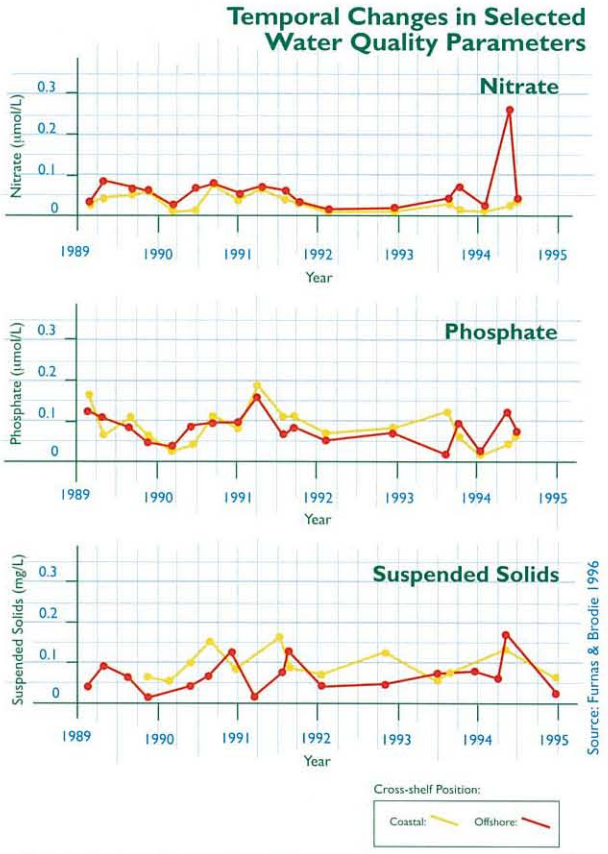
Most species also show cross-shelf gradients. In the Cairns and Innisfail areas, cross-shelf gradients in most water column characteristics are strongly evident. Particulate species have higher concentrations in nearshore areas and cross-shelf concentration differences are of the order of threefold. These cross-shelf patterns indicate that in the absence of local river run-off, the very low dissolved nutrient conditions which prevail in mid-shelf and lagoonal waters of the Great Barrier Reef are also characteristic of shallow nearshore waters.



Water quality parameters change with cross-shelf position. Increasing water depth indicates increasing distance from the coast.

Seasonal and temporal trends

A number of parameters (salinity, nitrite, particulate nitrogen, dissolved organic phosphorus and chlorophyll) show seasonal differences in concentrations. Most of the observed seasonal and cross-shelf variability in nutrient and suspended matter concentrations is likely due to short-lived event processes (upwelling, winds, resuspension) which largely affect local or regional nutrient distributions. Time series of water quality parameters in the well-sampled Cairns sector between 1989 and 1994 are characterised by distinct temporal variability, but lack an overall temporal trend.



Time series of water quality parameters measured in the area around Cairns show distinct temporal variability, but no overall trend.

Speciation trends

Phosphorus and nitrogen exhibit different speciation patterns in coastal and offshore waters of the Great Barrier Reef. Overall, most (60–70%) of the fixed nitrogen in the water column is in the form of dissolved organic nitrogen (DON), the composition and activity of which is largely unresolved. Particulate nitrogen (PN) comprises much of the remaining water column nitrogen. In contrast, particulate phosphorus (PP) is the dominant form of phosphorus in nearshore waters. Offshore, phosphate, dissolved organic phosphorus (DOP) and particulate phosphorus are present in roughly equal amounts. Slight nearshore declines in dissolved phosphorus concentrations in nearshore samples suggest that either nearshore sediments are a sink for phosphorus, or more likely, that soluble phosphorus is transformed to particulate form and exported away from the coast.

Great Barrier Reef waters in flood and cyclone conditions

Burdekin River plumes in the flood events of 1980 and 1981 were detected by lowered salinity from the mouth of the river north to Cairns and 40 km across the continental shelf. In the plume associated with cyclone Joy (1991) salinity dropped to 22 parts per thousand 25 km east of Magnetic Island with concurrent rises in chlorophyll concentrations, a change in dominant phytoplankton species to diatoms and the presence of enhanced larval fish populations. The Fitzroy River plume on a number of days during the cyclone Joy floods of 1991, reached the Capricorn–Bunker group of reefs 200 km from the mouth of the river. Salinities were lowered to 28 parts per thousand and some damage to coral appears to have occurred. For much of the three-week period of the major plume, low salinity water (down to eight parts per thousand) surrounded the reefs in Keppel Bay causing major coral mortality.

Substantial increases in chlorophyll and particulate nutrient species, of the order of 20 times, are evident during the nutrient pulses associated with river discharge. Resulting algal blooms are short-lived. In these cyclonic and flood plume conditions inshore reefs and seagrass meadows are subject to the highest nutrient concentrations they experience throughout the year. The effects on inshore ecosystems of these nutrient-rich pulses of river discharge are only partly understood.

Sediments

Sediments discharged from rivers are deposited close to the coast predominantly in northward-facing bays. Recent sediments discharged from the Great Barrier Reef catchment are likely to be elevated in nutrient content by changes in land use and fertiliser use in the catchment. Evidence of agricultural and mining use of catchments can be detected in offshore sediments. However, nearshore Great Barrier Reef sediments do not appear to have excessively high nutrient concentrations. Although sediments discharged in rivers from agricultural catchments are normally quite high in nutrients, these nutrients may have been lost from the sediment before sediment deposition occured.

TABLE 2 Minimum salinities and maximum nutrient, chlorophyll and suspended particulate matter concentrations sampled in Great Barrier Reef waters following cyclonic events

Cyclone	Date	Shelf Region Sampled	Minimum Salinity (ppt)	NH_4 (µmol/L)	NO_2 (µmol/L)	NO_3 (µmol/L)	DON (µmol/L)	PN (µmol/L)	PO_4 (µmol/L)	DOP (µmol/L)	PP (µmol/L)	$Si(OH)_4$ (µmol/L)	Chlorophyll a (µg/L)	Phaeophytin (µg/L)	Suspended Solids (mg/L)
Winifred	Feb-86	Central In/Offshore	29.30	5.00	0.29	3.15			0.60			48	17.90	6.10	
Jason	Feb-87	Central Inshore	29.84	1.25	0.24	7.8			0.19			76			
Charlie	Mar-88	Central Inshore	28.70	2.81	0.36	3.27			1.13			56	2.96	0.80	56
Aivu	Apr-89	Central In/Offshore	34.42	11.15	0.33	0.79	8.7	10.8	0.48	0.18	0.43	29	0.93	1.43	
Joy	Jan-91	Southern Inshore	7.90	4.06	1.20	2.41	25.2	11.2	1.58	1.98	0.85	174	20.1	1.33	36
Sadie	Feb-94	Central Lagoon	29.20	0.44	0.02	1.20	17.8		0.06	0.32		25	1.33		3
Violet	Mar-95	Central Lagoon	2.2	1.3		14	11		0.32	0.2		110	1.6	2.5	26
Ethel	Mar-96	Northern Inshore	12.5		1.13	1.3	9.65	10.32	0.58	2.67	0.96		1.99	1.04	62
Justin	Mar-97	Central Inshore	0	7.46	0.52	17.22	27.1		2.46	0.93	2.34	220.5	4.62	3.03	
Sid	Jan-98	Central Inshore	0	12.8	0.48	11.98	28.93		0.66	1.61		126.1	2.52	1.345	672

Heavy Metal Status

Sediments

Low levels of a range of metals have been detected in surface sediments in several Queensland ports. Elevated concentrations of copper which were attributed to past use of copper-based marine antifouling paint have also been found in Cairns Harbour. Elevated concentrations of nickel, chromium, iron and zinc which were associated with nickel ore loading berths have also been detected in the Port of Townsville. Sediment metal levels in Torres Strait and the Raine Island area during 1992 and 1993 were low and comparable with concentrations found elsewhere in unpolluted tropical marine sediments. A recent study of sediments from 13 intertidal sites along the Great Barrier Reef coast showed highest concentrations of metals were generally present at sites adjacent to human settlement and agricultural influences. Metal concentrations were usually well below levels expected to be of environmental concern.

Animals and plants

The tissues of a variety of animals and plants have been examined for heavy metal content. Corals collected in the vicinity of Townsville in the 1980s contained comparatively high concentrations of metals. Extremely high concentrations of arsenic have been observed in the tissues of various bivalves collected from Great Barrier Reef waters although this accumulation is probably a natural phenomenon. Trace metal concentrations in reef algae in 1980 were low and indicative of an unpolluted environment. Seagrass from a recent study (1997) of intertidal sites along the coast showed highest concentrations of metals in samples from near human settlement and levels were correlated with the levels in sediments from the same sites.

Analysis of tissue samples from dugongs collected from Torres Strait and Townsville between 1974 and 1978 detected unusually high concentrations of iron and zinc in liver tissue and high concentrations of cadmium in kidney tissue.

Levels of iron, zinc, cadmium and cobalt in the liver and cadmium in the kidney were positively correlated with age of the animal. Similar metal concentrations were reported in tissues from three dugongs stranded in northern Australia in 1984 and from dugongs collected from Torres Strait and the Gulf of Carpentaria in 1992. Metal levels in some dugong tissues are high enough to have health implications for human consumers.

Pesticide and Toxic Organic Contaminant Status

Seawater

Relatively low concentrations of pesticides (e.g. DDT and lindane) and their breakdown products were reported in air and water samples collected from the Coral Sea in 1981. This was in contrast to a later study where lindane was detected in relatively high concentrations in Coral Sea waters in 1987.

Sediments

A limited number of Great Barrier Reef sediments have been analysed for organochlorine contamination. Lindane was detected in sediments from the mouth of the Burdekin River in 1984 and 1985. Polyaromatic hydrocarbons have also been detected in Great Barrier Reef sediments. Highest concentrations were present in sediments collected from Townsville Harbour and were a consequence of fuel discharges and motor exhaust emissions to the water. Polyaromatic hydrocarbon concentrations in Gladstone Harbour sediments were also comparable with concentrations present in polluted marine sediments elsewhere. Low levels of polyaromatic hydrocarbons were found in sediments adjacent to boat landing and mooring areas around Green and Heron islands.

Recently (1998) DDT, DDE, lindane, diuron and dieldrin were detected in trace amounts in sediments collected from wet tropics river mouths.

Plants and animals

In 1998 diuron was detected in seagrasses at Cairns, Cardwell, Pallarenda and from Cleveland Bay. Dioxins were detected in seagrasses at all sites with concentrations being similar to those present in the sediment. A range of PCB congeners were also detected in seagrass samples.

Pollutant concentrations present in Great Barrier Reef invertebrates have only been investigated in a limited number of species. Studies in the 1970s found low concentrations of pesticides and polyaromatic hydrocarbons in a variety of reef biota. Average muscle tissue concentrations of chlorinated organics in coastal marine fish species collected in the vicinity of Townsville between 1989 and 1993 were low compared to samples from other urbanised centres. Further sampling in 1992 and 1993 of fish livers showed low levels of DDE and dieldrin in some samples.

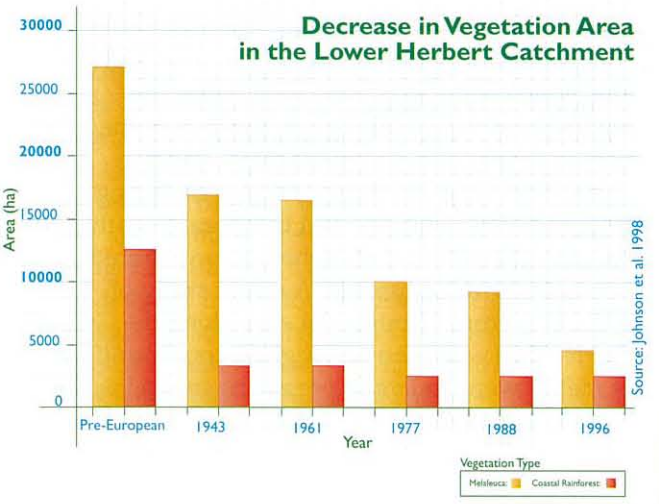
Organochlorine compounds have also been detected in dugong tissue samples. Compounds found include lindane, dieldrin and polychlorinated dibenzo-dioxins. Polyaromatic hydrocarbons were not detected in any of the animals. It is not known whether the levels detected pose any threat to the health of the biota or the ecosystem generally.

PRESSURE

Pollution Sources on the Great Barrier Reef catchment

Changes in land use

The watersheds of rivers in north and central Queensland have been extensively modified since European settlement by clearing followed by forestry, mining, urbanisation and agriculture. Clearing of forest and woodland has continued throughout the last 130 years with early loss of rainforest areas in coastal lowlands and on the ranges and tablelands, loss of coastal wetland forest and extensive loss of open woodland. In the Herbert catchment *Melaleuca* wetlands have been reduced in area from 30 000 ha in pre-European times to less than 5000 ha in 1996 while in the lower Johnstone catchment a 78% loss occurred between 1951 and 1992. In the Fitzroy catchment, during the brigalow (*Acacia harpophylla*) woodland clearance schemes (1950 to 1975) approximately 4 000 000 ha of brigalow woodland were cleared for conversion to



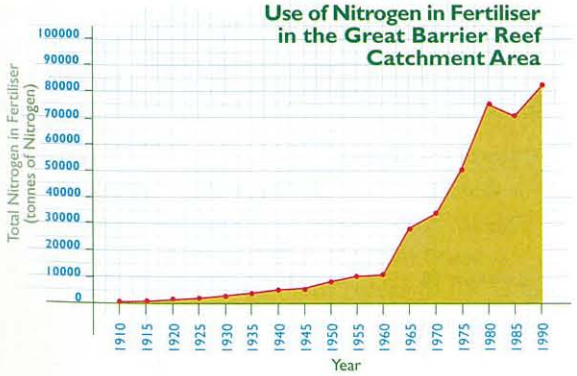
grasslands for beef cattle grazing. Forest and woodland clearance in Queensland has been quantified from satellite imagery.

Human population densities in north Queensland are low and concentrated along the coastline. Only five cities have populations exceeding 40 000. Population numbers are increasing steadily with an estimated total Great Barrier Reef catchment population of 1 200 000 in 1995. Grazing of cattle for beef production is the largest single land use (77%) in the catchment with cropping, mainly of sugarcane (3%), and urban/residential development (3%) considerably smaller in areal extent. Other significant land uses include mining (coal and metalliferous) and cotton cropping.

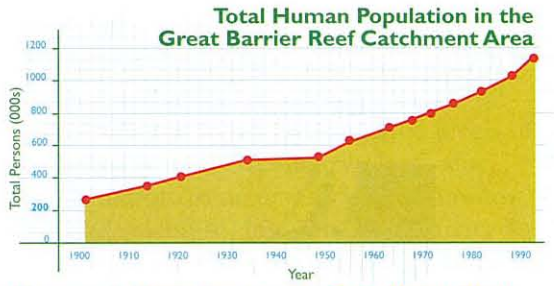
Beef cattle numbers are approximately 4 500 000 with the highest numbers in the Fitzroy catchment. The sugarcane cultivation area has increased steadily over the last 100 years with a total of 390 000 ha reached by 1997. The cultivation area is located near the coast in many of the lowland areas of catchments. Fertiliser use is closely linked to sugarcane cultivation as the largest crop on the Great Barrier Reef catchment. With both continuously increasing cultivation area and increasing rates of application, total application has increased rapidly since 1950. Other industries with significant expanding land use (and fertiliser use) are cotton (mostly in the Fitzroy catchment) and horticulture (in many catchments), particularly bananas.

Sediment and nutrient discharge

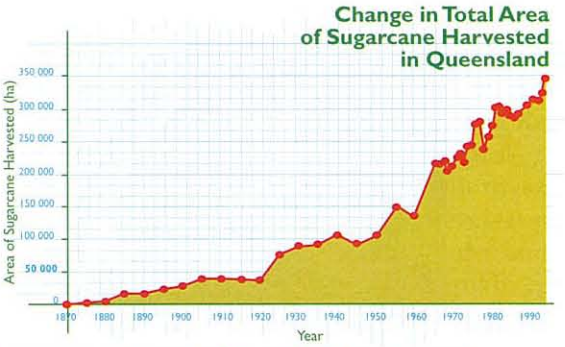
Estimates of total river discharges of sediment and nutrients (nitrogen and phosphorus) from the Great Barrier Reef catchment have been derived from models relating erosion and regional land-use patterns. The importance of the large 'dry' catchments where cattle grazing is the dominant land use is evident. Overall, 66 % of the estimated nutrient and sediment flux is



The amount of nitrogen applied to the Great Barrier Reef catchment in the form of fertiliser has increased markedly since 1910.



The human population living on the Great Barrier Reef catchment has increased steadily since 191



Sugarcane production in Queensland has increased since 1870.

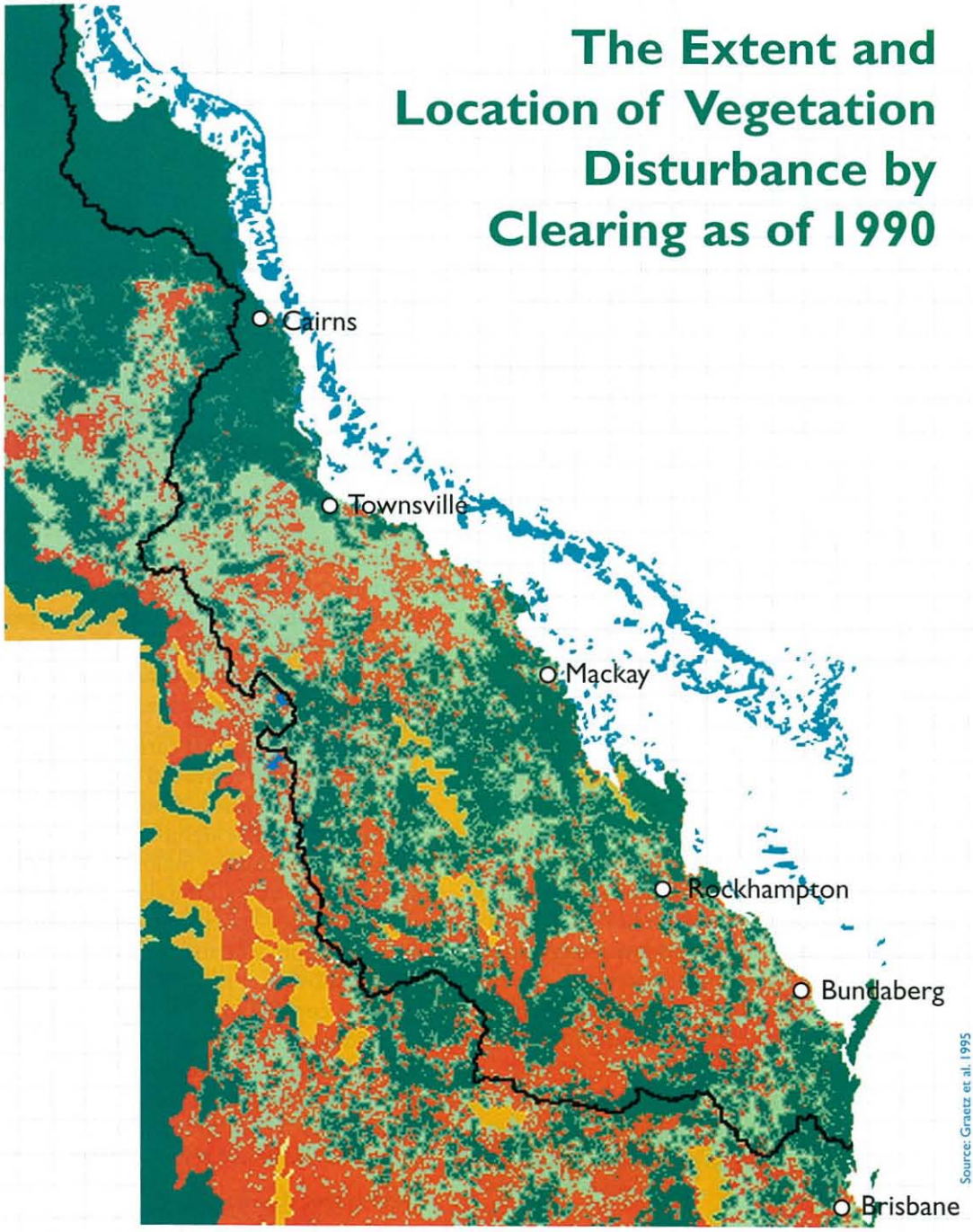
estimated to come from grazing lands, with 8% from cropping lands and 26% from 'pristine' areas. Overall, the total run-off flux of sediment is estimated to be four times that prior to European settlement.

Sugarcane and banana farming cause high losses of nitrogen from fertilised fields. At regional scales, nitrogen losses from fertilised canegrowing sub-catchments are detectable in river systems during major flood events. While there are relatively little data at present on area- and catchment-specific losses of sediment and nutrients from grazing lands the limited data clearly show that run-off and soil erosion are strongly correlated with vegetation cover. This is significant as extensive removal of grass and vegetation cover occurs in grazing lands during extended drought periods. Recent siltation of estuaries provides circumstantial evidence for increased sediment removal from catchments.

Freshwater discharge

In many overseas catchments loss of forest cover, reduction in vegetation cover, hardened surfaces in urban and transport systems and drainage schemes have been shown to produce higher rates of water run-off. Downstream effects of this include larger floods and greater volumes of discharge as well as a faster, more concentrated discharge pattern. Offshore ecosystems are likely to experience more intense low salinity events than from natural catchment conditions.

The Extent and Location of Vegetation Disturbance by Clearing as of 1990



Low salinity events from cyclonic rainfall floods cause coral reef bleaching and mortality. Massive rainfall and flooding events in 1918 caused coral mortality in the Mackay to Bowen region. More recently, the January 1991 Fitzroy River flood caused almost complete mortality in the upper layers of the Keppel Island reefs. Other recent (1994) coral bleaching and mortality at Pandora Reef and throughout the inner Great Barrier Reef (1998) may also have been enhanced by low salinity events but simultaneous high temperatures and high turbidities make it difficult to attribute the principal cause.

While it is likely that Great Barrier Reef catchments, in their modified condition, now produce larger and more intense water discharge no estimates or evidence for this have been produced. The presence of dams on many Great Barrier Reef rivers may also act to moderate flows during periods of small to moderate flow. An estimated 13% (8 km^3) of the average annual discharge from the Great Barrier Reef catchment (60 km^3) is potentially able to be captured in existing reservoirs.

Pesticides and other toxic organics

The principal use of pesticides on the Great Barrier Reef catchment is in agriculture, with minor use for urban termite control and public health mosquito control. In the sugar industry the types and quantities of pesticides in present use have been documented showing the insecticide chlorpyriphos and the herbicides atrazine, diuron, 2,4-D, glyphosate and ametryn in common use. The organochlorine pesticides aldrin, lindane, DDT, dieldrin and heptachlor were also in common use for sugarcane cultivation and other crops in the past but use has been discontinued for many years. In the cotton industry the organochlorine endosulfan is still in wide use. Dioxins (a type of organochlorine compound) are formed when chlorine-containing organic materials are burnt. It has been shown that the burning of sugarcane trash can produce dioxins. However, dioxins may have a large variety of sources and attribution of dioxins found in biota to particular sources is difficult.

Pesticide residues are commonly detected in stream waters, sediment and biota after rainfall events and it is expected that some of these residues will be exported from rivers to the Great Barrier Reef. Significant levels of endosulfan and atrazine have been found in the Fitzroy River and low levels of 2,4-D, atrazine and 2,4,5-T in the Johnstone River.

Heavy metals

Mining, metal refining and manufacturing, agriculture and other industrial processes all have the potential to release increased levels of the toxic heavy metals (primarily lead, zinc, copper, cadmium, mercury, nickel, chromium, arsenic and selenium) into the Great Barrier Reef catchment and hence on to the Great Barrier Reef. Little evidence of elevated metal levels from present-day mining exists in rivers or the Great Barrier Reef. Elevated copper levels, present in Fly River water, from waste from the Ok Tedi gold and copper mine in Papua New Guinea have not been detected in water, biota and sediments of the northern Great Barrier Reef. Evidence for elevated metal levels from past mining activity has been found off the Burdekin River. Significantly elevated mercury levels (up to 20 µg/kg) were found in sediment cores and this has been linked to the use of mercury in gold recovery during the heyday of gold mining in Charters Towers (1870–1890).

Acid sulphate soil run-off

Acid sulphate soils can be found along the complete Great Barrier Reef coast. While some well-known areas, such as east of Trinity Inlet, are recognized as problem areas few major instances of acid sulphate run-off and subsequent fish kills or 'red spot' disease in fish have been documented. In recent years development of low-lying coastal lands for sugarcane cultivation (e.g. the Tully–Murray floodplain), tourism development (e.g. Point Hinchinbrook at Oyster Point) and ponded pasture for beef cattle production (e.g. coastal areas north of Rockhampton) have raised concerns of acid sulphate soil problems. Little data are available on existing problems but increasing incidence of 'red spot' disease is being reported.

Litter

Stormwater discharge, particularly from urban areas, carries quantities of litter into the Great Barrier Reef. Surveys of litter on Great Barrier Reef islands have shown that much of the material is ship-sourced but a significant proportion may come from terrestrial sources. As well as aesthetic concerns litter may be implicated in the entanglement of marine animals and may also cause ingestion problems for birds and turtles.

Extent of terrestrial run-off

River water entering the Great Barrier Reef normally flows northward and is held near the coast by a combination of factors including wind

forces and the physical structure of the coast. Direct effects of sediment and water derived from river run-off on Great Barrier Reef ecosystems are thus largely concentrated near the coast. Coring studies in river estuaries and mapping of sediments on the continental shelf indicate that most of the sediment transported by river systems is deposited within 10 km of the coast. Northward facing embayments, in particular, trap large amounts of sediment and these sites reveal changes in inputs consistent with historical land-use patterns in the adjoining catchments. In particular, mercury from historic gold mining activity and recent use of fungicides containing mercury in sugarcane cultivation can be detected. Similarly cadmium, an impurity in superphosphate fertiliser, has also been detected. Only small amounts of terrestrial sediments appear to reach the outer-shelf reefs, primarily during major cyclonic floods when river plumes can cover extensive areas of the shelf. Mid- and outer-shelf reef sediments contain very low proportions of terrestrially derived sediments.

Following major flooding in the Fitzroy River catchment in 1991 low salinity plume water was observed offshore for a period of three weeks. Low salinity water (down to eight parts per thousand) caused significant coral mortality to the fringing coral reefs around the Keppel Islands. In the Capricorn–Bunker group of reefs, more than 200 km from the mouth of the river, salinities as low as 28 parts per thousand were recorded and some damage to corals was observed. Winds appeared to be a major factor influencing the movement of the plume on the shelf. Plumes from rivers on the wet tropics coast are normally held near the coast by south-east winds (e.g. in cyclone Violet in 1995) but may reach mid- and outer-shelf reefs in low wind conditions (e.g. in cyclone Sadie in 1994).

Potential Effects of Pollutant Run-off

Clear long-term and regional-scale effects on Great Barrier Reef ecosystems from accelerated run-off of sediment and nutrients have proven difficult to detect. Three significant problems are 1) the frequent natural disturbance of Great Barrier Reef coastal ecosystems by cyclones and floods, 2) the relatively short term of careful observation (ca. 15 years) relative to the natural disturbance frequency, and 3) the lack of unambiguous pristine controls for comparison. Many of the major changes in land use and modification occurred before monitoring of coastal and reefal ecosystems was initiated.

Seagrass and corals living along the coast, have recruited, grown and evolved in the presence of natural freshwater, terrestrial nutrient and sediment inputs. The ability of individual corals to deal with this is recognised but varies between species. Extended periods of freshwater inundation can damage reefs and kill corals. Similarly large areas of seagrass in Hervey Bay were killed by flood plumes from the Mary River and Koolan Creek in 1992. Over longer periods, high sediment and nutrient loads are also known to degrade coastal ecosystems.

Coral reefs

Increased nutrient supply can enhance the growth of turf algae and macroalgae. This effect has been demonstrated in numerous coral reef systems worldwide particularly in Kaneohe Bay, Hawaii. Perhaps less dramatic, but nonetheless clear, demonstrations of links between sediment, sewage and nutrient inputs and changes to reef systems have been recorded at other sites. In addition the enhancment of phytoplankton growth from increased nutrient supply leads to increased filter feeder (e.g. tubeworms, sponges, bivalves) growth. Macroalgae may overgrow coral, both competing for space and shading the colonies. Filter feeders compete with coral for space and many are eroding organisms which bioerode the reef structure. Neither macroalgae nor most filter feeders add to reef consolidation through calcification. Excessive phosphorus concentrations weaken the coral skeleton by making it grow with a less dense structure and making the colony more susceptible to damage from storm action. A general reduction in calcification of the reef system also occurs. Suspended and resuspended sediments can bury hard corals, increase turbidity, reducing the depth to which essential light can penetrate, and alter the ecology and nutrient dynamics of reef surfaces.

Systematic monitoring of reef benthos throughout the Great Barrier Reef shows no general patterns of degradation but the record is short – less than ten years. Historical photographs of reefs (generally reef-flats exposed at low tide) have been compared with current conditions. The comparisons show less coral cover is now present on some fringing reef-flats than in periods before 1960. Other reefs show no change in condition. Apparent changes of inshore reefs from a hard coral dominated state to a macroalgal or soft coral dominated state have been observed but it is not yet determined whether these changes are part of a natural successional process or symptoms of long-term eutrophication.

Movement of flood plumes is highly dependent on wind speed and direction. Plumes from rivers on the wet tropics coast are normally held near the coast by south-east winds (e.g. in cyclone Violet 1995) but may reach mid- and outer-shelf reefs in low wind conditions (e.g. in cyclone Sadie 1994).

Seagrass systems

Close proximity to land means seagrasses are likely to be affected by material flowing from land and vulnerable to changes in coastal processes. Recent studies of the factors contributing to seagrass decline have shown that increased human-induced inputs to the coastal zone are often linked to seagrass loss. Effects of eutrophication on seagrass meadows are most severe in sheltered habitats with reduced tidal flushing, where nutrient loadings are both concentrated and frequent, and where temperatures fluctuate more widely than in areas with greater water exchange.

The distribution and growth of seagrasses is regulated by a variety of water quality factors such as temperature, salinity, nutrient availability, substratum characteristics, turbidity and submarine irradiance. Once impacted, seagrass colonisation and regrowth can be very slow, or nonexistent because of possible ongoing impacts and poor dispersal capabilities of most seagrass species.

On nearshore Great Barrier Reef reefs, water column nutrients are highly variable, ranging from non-detectable to levels indicative of a eutrophic state. Inshore seagrass systems are episodically subjected to high dissolved nutrient and suspended loads more typical of a eutrophic system during monsoonal flood conditions. Water samples taken in flood plumes have consistently recorded elevated ammonia and phosphate levels of 0.6–4.2 µmol/L and 0.13–1.98 µmol/L respectively and nutrient levels have remained high in inshore waters for periods from a number of days to weeks. Under these conditions severe effects on seagrass can be expected.

Planktonic communities

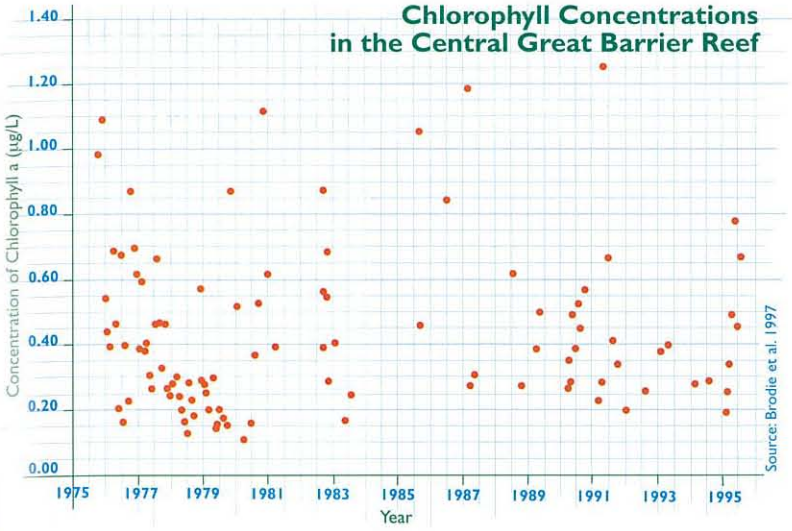
Nitrogen and phosphorus are often limiting nutrients for the growth of phytoplankton, especially in warm, clear tropical waters where light is unlikely to be limiting. Thus phytoplankton flourishes in nutrient-enhanced conditions leading to decreased water clarity and reduced light for coral growth on the bottom.

Evidence of eutrophication in the Great Barrier Reef phytoplankton record is unclear. Studies which have repeated measurements of phytoplankton composition and abundance first made in 1928–29 in a single area near Low Islands have found significant differences and the claim has been made that the differences show the system to be in a higher nutrient condition than at that time. Some evidence of eutrophication at local scales has been reported and claimed more generally for the whole Great Barrier Reef. Results from broadscale phytoplankton surveys in the Great Barrier Reef on the other hand show biomass and species composition consistent with an unimpacted system. Great Barrier Reef waters generally show no indications of long-term elevated nutrient or chlorophyll levels or recent (last ten years) rises in mean concentrations.

RESPONSE

Water quality has been identified by the Great Barrier Reef Marine Park Authority as a critical issue for the management of the Great Barrier Reef Marine Park. Management of water quality is difficult as many of the activities causing the problems lie outside the boundaries of the Marine Park and involve multiple authorities. The Authority is working with various government agencies and industry organisations to monitor and reduce the effects on water quality of land-based sources of pollution. The 25 Year Strategic Plan for the Great Barrier Reef World Heritage Area identifies integrated land and coastal management as an

Canefields around Tully, with Hinchinbrook Island in the background



Chlorophyll concentration in the central Great Barrier Reef is highly variable but between 1975 and 1995 no trend, either up or down, was discernible.

important process to minimise pollutant input from the land to the World Heritage Area.

The management of water quality in the Marine Park involves policy decisions such as sewage discharge standards, cooperative arrangements between government and industry to reduce inputs, case-by-case management of activities such as dredging, and enforcement of Australian Government legislation such as that regulating the dumping of substances from ships. The reduction in nutrient loads entering the Marine Park from coastal catchments is seen as the most important water quality issue facing the World Heritage Area. For more detailed information on the management of water quality, refer to *Management Status – Water Quality and Coastal Development*.

Management of catchment pollution sources is primarily under the control of Queensland state agencies. The main broadscale management practice being introduced is Integrated Catchment Management. This program is the primary tool of the Queensland Government to reduce catchment-based pollutant discharge to aquatic systems and the coastal zone. Local and State governments, land-holders, and community and farmer organisations join together to manage catchments on a whole-catchment basis. With coordination through the Integrated Catchment Management process, some of the desired reductions in pollutant inputs to the coastal zone should be achieved.

Some recent land management changes in rural industries should help reduce land-based sources of sediment and nutrient run-off. The most notable examples are the green cane harvesting, trash blanketing and minimum tillage techniques in sugarcane cultivation. In rangeland grazing situations, fencing off streamlines to prevent cattle access and subsequent bank erosion is being trialled. Codes of practice are being developed for many agricultural industries to address environmental issues related to the industry. They have been prepared for the cotton and sugar industries in 1998 while a dairy farmers' code is also under development.

Wetlands are vital for the protection of the Great Barrier Reef as they ameliorate the impacts of run-off from catchments. Coastal wetlands disperse and slow the velocity of run-off, allowing entrained sediments and nutrients to settle out before they enter Great Barrier Reef waters. Preservation of remaining wetlands along the coast adjacent to the World Heritage Area and the rehabilitation of degraded wetlands are important to the management of Reef water quality.

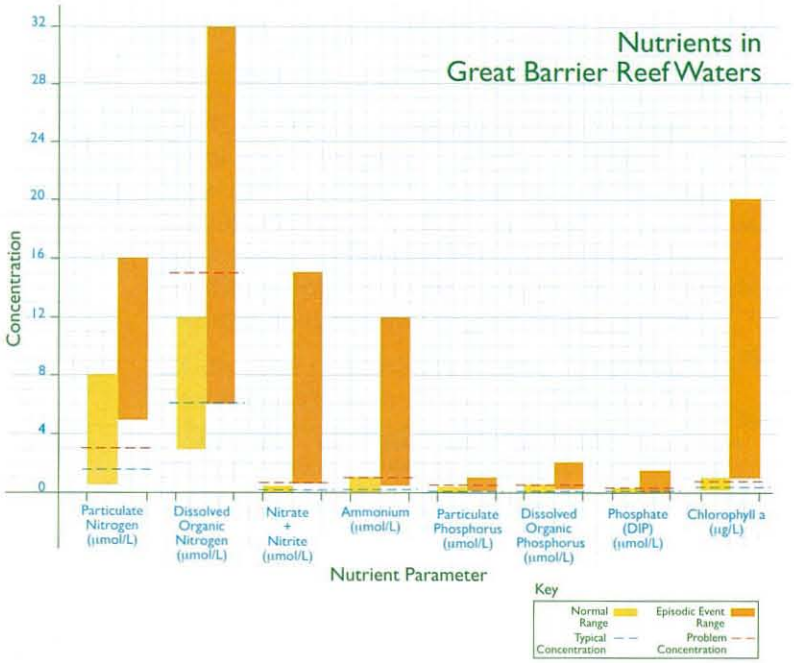
Sewage discharge is regulated in the Marine Park. Where sewage and other effluents enter the Marine Park directly through an outfall, the discharges are regulated through the Great Barrier Reef Marine Park Authority permit system. Under present policy, sewage must be tertiary treated (i.e. nutrient reduction) followed by marine discharge, or land reuse of secondary or tertiary treated effluent with minimal marine discharge. Most outfalls in the Marine Park now meet the standard.

Large coastal cities adjacent to the World Heritage Area have secondary treatment sewage systems, with outfalls into coastal streams or the ocean. At present, no coastal cities discharge sewage directly into the Marine Park. Many local government agencies now have policies to maximise reuse of effluent and some have already ceased ocean discharge. Discharge of wastewater into the ocean from industrial installations and aquaculture facilities is controlled under the Queensland *Environmental Protection Act 1994* through a licensing system.

SUMMARY

Water quality in the World Heritage Area may be adversely affected by a variety of land-based pollutants including sediments, nutrients, heavy metals, toxic organic contaminants and pesticides. While isolated instances of elevated levels of heavy metals, toxic organics and pesticides have been recorded particularly near urbanised or industrialised sites, the primary concern is nutrient run-off from the land.

Unnaturally high concentrations of nutrients in Great Barrier Reef waters are generally associated with cyclone or flood events and are usually short-lived. Nutrient concentrations vary across the shelf and are generally low except in flood conditions. On nearshore reefs, water column nutrients are highly variable, ranging from non-detectable to levels indicative of a eutrophic state. To date, water quality monitoring has not shown any distinct trend over recent years.



Variation in nutrient and chlorophyll concentrations in open waters of the Great Barrier Reef lagoon. Ranges are shown for normal conditions and episodic events (cyclones and floods). Values are shown for typical and problem concentrations. Problem concentrations are those that would be considered a problem if they persisted for more than a month.

Discharge from catchments adjacent to the World Heritage Area is dominated by large flood events due to cyclone or monsoonal rainfall. While nearshore reef communities have always been influenced by terrestrial run-off, land-use changes and practices have increased sediment and nutrient inputs in recent times. Discharge of sediments and nutrients to the Great Barrier Reef has increased by four times over the last 100 years. Nutrients reach concentrations many times their baseline values during flood events. The effects on inshore ecosystems of these nutrient-rich pulses of river discharge are not well understood. Coastal wetlands play an important role in filtering out sediment and nutrients during such flood events and their loss represents an important historical and potentially ongoing pressure.

Reduction in nutrient loads to the Marine Park from coastal catchments is a key management issue for inshore ecosystems. Regulation of discharges, integrated catchment management, changing land management practices and wetland protection should help decrease sediment and nutrient inputs to the Great Barrier Reef.

STATE

The status of mangrove systems involves three factors: biomass (tree height and density), diversity of species and total spatial coverage. Each of these factors affects the ability of mangrove forests to support and sustain dependent nearshore life forms and to influence coastal geomorphology.

Mangroves are important nursery grounds for many fish and crustacean species.

Mangroves within and bordering the Great Barrier Reef World Heritage Area are some of the most pristine and diverse mangrove forests in the world. These areas harbour more than half the number of all mangrove species in the world. Individual estuarine stands may contain up to 28 species and there are at least 37 species in the entire World Heritage Area. This wide diversity of species is reflected in an equally diverse range of structural forms in a rich and varied string of estuarine habitats. These habitats support a wide range of dependent organisms which interact with both the marine and terrestrial nearshore communities.

Mangrove forests occupy approximately 2070 km^2 spread along the length of the coast adjacent to the Great Barrier Reef World Heritage Area. About 95% of this mangrove forest is on the border of the World Heritage Area, not actually inside it. However, all mangrove forests adjacent to and in the World Heritage Area are interconnected with and form a critical part of the Great Barrier Reef ecosystem. Many species of animals, particularly some fishes and crustaceans, spend part of their life cycle living in the mangrove forest and the remainder living in other parts of the ecosystem, such as coral reefs.

Unfortunately, the area of mangrove forest existing before European settlement of Australia has not been estimated. Thus, we do not know whether this area has decreased over the long term, during the time of European settlement.

Studies over shorter time scales have shown that the area of mangrove forest has increased, at least in some areas. For example, in the Johnstone River catchment, the total mangrove area increased from 176 to 202 ha (i.e. by 14.8%) between 1951 and 1992. An increase in mangrove area has also been observed in Trinity Inlet, near Cairns. It is important to note that whilst the total area of mangroves has increased in some areas, such increases are not necessarily widespread.

PRESSURE

Mangroves are subject to a number of pressures from human activities. These include:

- clearing of mangrove forests for other uses,
- structures such as breakwaters changing water flow and sediment deposition patterns,
- chronic stress from reduced air and water quality, and
- catastrophic events such as shipping spills.

For the most part, such impacts are either being managed, such as clearing for other uses, or only occur rarely, such as catastrophic shipping spills. A major concern for mangrove forests is the issue of cumulative impacts where a series of instances of seemingly insignificant damage eventually result in more serious damage to the mangrove community of an area.

Australia has the third largest area of mangroves in the world.

RESPONSE

Mangroves in Queensland, along with all other marine plants, are protected under the Queensland *Fisheries Act 1994*. Protection of marine plants under the Act is the responsibility of the Queensland Department of Primary Industries which has an extensive and comprehensive policy for dealing with potential impacts on marine plants, particularly mangroves. This policy considers the wide range of pressures on mangroves, including the issue of cumulative impacts.

All marine plants are protected from unlawful damage or removal. Marine plants may be damaged or removed lawfully, with appropriate permits from the Queensland Department of Primary Industries. The process for deciding whether to issue such a permit is complex. Typically, a permit is only issued if the permittee undertakes mitigation for the area of marine plants affected. Mitigation can involve input into research, support of extension activities or surrendering privately owned land to the State for protection. In this way, areas of important habitat, including some freshwater wetlands that are otherwise not protected, have been afforded protection by being transferred from private ownership to state ownership. In some cases, mitigation is sought through planting an area of mangroves equal to that being removed. This strategy has had mixed success in the past and today is only used when, after careful assessment, it is considered likely to be more successful than natural colonisation.

The Queensland Department of Primary Industries has declared Fish Habitat Areas throughout tidal areas of Queensland. Their purpose is to enhance existing and future fishing activities and to protect the habitat upon which fish and other aquatic animals depend. Declaration as a Fish Habitat Area affords a high level of protection to marine and estuarine ecosystems in specific locations. Marine plants, including mangroves, are even more highly protected in Fish Habitat Areas than they are generally under the Queensland Fisheries Act. Adjacent to the Great Barrier Reef World Heritage Area there are 44 Fish Habitat Areas, covering a total of 466 827 ha.

Mangroves receive a high level of protection. It is crucial that this is continued as mangrove forests form an essential part of the ecosystem that makes up the Great Barrier Reef World Heritage Area.

SUMMARY

Although most mangrove forests lie outside the Great Barrier Reef World Heritage Area, they are closely connected both physically and functionally. Mangroves are home to a variety of organisms that spend part of their time in the adjacent World Heritage Area, while mangrove roots play an important role in stabilising coastal sediments and reducing erosion and turbidity. No major declines in mangrove area have been recorded during the last 40 years. Clearing and damage to mangroves and other marine plants are closely regulated under legislation administered by the Queensland Government.

Environmental Status | Island Plants

STATE

The flora and vegetation of the continental islands and coral cays of the Great Barrier Reef World Heritage Area are exceptionally diverse given the small area of land involved.

There is a total of 2211 plant species on the more than 550 continental islands. This is about a quarter of the total number of species for Queensland in only 0.1% of the area of the State. This island plant community is dominated by rainforest species (48% of species present) together with open-forest species (46%) and coastline species (6%). Sixty-two of the species are currently listed as rare or endangered and two species are found only in the World Heritage Area.

Introduced plant species are present on the continental islands of the World Heritage Area, but in lower numbers of species than usually found on developed islands in other regions. In different areas of the Great Barrier Reef the percentage of introduced species on islands varies from 4.7 to 14.4%. For comparison, 47% of the plant species on Hawaii are introduced.

Plant communities on the more than 230 coral cays have fewer species with 350–400 species in the northern region and about 140 in the south. The northern region is home to many rainforest species and relatively few (only 15%) introduced ones, whereas the southern region has a relatively large number (55%) of introduced species. Coral cay vegetation, particularly the *Pisonia* rainforest, provides important nesting sites for seabirds. Seventy per cent of the entire Australian coral cay *Pisonia* rainforest occurs on the cays of the Capricorn–Bunker group.

PRESSURE

Colonisation by introduced species is a pressure on the plant communities of islands. Disturbance of natural plant communities by grazing and human activities often promotes and accelerates colonisation by introduced species. These species may have the ability to out-compete native species, thus changing the community structure on islands in the Great Barrier Reef World Heritage Area.

Fire is often used as a management tool on continental islands. Although fire does have a place in management strategies, it should be used cautiously as a high incidence of fires may reduce biodiversity.

First noticed in 1993, an infestation of scale insects has defoliated most of the *Pisonia* trees on Tryon Island, causing a major change to the forest habitat on this island. The scale insect appears to occur naturally in low numbers on islands throughout the Pacific, and the causes of this outbreak are unknown. A monitoring program has been implemented to document the progress of the infestation and to detect any new outbreaks on adjacent islands.

Pisonia trees provide nesting and roosting sites for black noddies, one of the few seabirds that nest in trees.

RESPONSE

Most islands within the Great Barrier Reef World Heritage Area are national parks under Queensland legislation. The management of most islands in the World Heritage Area is the responsibility of the Queensland Department of Environment and Heritage.

Generally speaking, a policy of minimum disturbance of native island vegetation will minimise problems of invasion by introduced species. Early detection and removal of new colonising species is recommended as, once a species is well established throughout an island, it is often difficult and expensive to control. Marine Park staff have a program of eradication or control of introduced plants and animals on most islands.

The degree to which fire is used as a management tool should be carefully considered on an island-by-island basis.

SUMMARY

The plant life of the continental islands of the Great Barrier Reef World Heritage Area is highly diverse (2211 species in total) with two species occurring exclusively in the area. Coral cays have fewer species (140–400 species) with southern cays being the least diverse. Grazing and plant introductions have been important pressures, but both are currently being addressed by management measures. A program of eradication or control of introduced plants and animals exists on most islands. With a few exceptions, islands in the World Heritage Area have protected status as State national parks.

Sixty-two plant species which occur on continental islands in the Great Barrier Reef are listed as rare or endangered.

STATE

More than 5000 km² of seagrass habitat have been mapped so far within the Great Barrier Reef World Heritage Area. While this is an impressive area, it represents less than 1.5% of the total World Heritage Area. However, continuing surveys carried out by the Queensland Department of Primary Industries are likely to discover further, possibly extensive, areas of seagrass habitat. Seagrasses are of great ecological importance as food sources for threatened or endangered species such as green turtles and dugongs, and nursery areas for juvenile prawns and fishes, some of which are of great commercial importance, for example, tiger prawns.

Seagrass habitat is found throughout the World Heritage Area: in estuaries, shallow coastal bays and inlets, coral reef platforms and in areas of more than 60 m depth between reefs. Fourteen species of seagrasses have been identified. Most of these are widespread but at least two may be endemic to north-eastern Australia.

Queensland Department of Primary Industries surveys, started in the 1980s, have documented about 3000 km² of coastal, shallow-water seagrass habitat and at least 2000 km² of deepwater seagrass habitat. More deepwater seagrass habitat is being discovered as surveys continue.

Even under natural conditions, seagrasses tend to die in some areas and colonise others fairly quickly. Therefore the distribution of seagrass habitat also changes and information from some of the earlier surveys may be out of date now. At several locations where two surveys, separated by several years, have been carried out, the degree of change observed depends on the spatial scale. Such areas include Shoalwater Bay, Hinchinbrook Island, and Trinity Inlet near Cairns. At scales of hundreds of metres, seagrass areas are not stable, changing markedly over time. However, at scales of hundreds of kilometres, the distribution is much more stable.

Few detailed studies of change in seagrass habitat over time have been made. Without this kind of study it is very difficult to be sure what effect human activities are having on seagrass habitat.

PRESSURE

Pressures on seagrass habitat include degraded water quality caused by increased human urban and agricultural development, trawling, and natural events such as cyclones.

Probably the greatest threat to seagrass habitat is land run-off and its effect on water quality. Increased sediments and nutrients in waters running from the land into the World Heritage Area can stress and even kill seagrasses. Such problems can be magnified for seagrasses because localities which provide shelter and water conditions ideal for productive seagrass habitat are often good sites for port development, and are at the downstream end of heavily impacted catchments. For further information on land-based effects on water quality, see *Environmental Status – Water Quality*.

Another human pressure on seagrass habitat is trawling. Most shallow-water seagrass habitat is protected from this potential impact (see *Response*) and dense deepwater seagrass habitat is usually avoided by trawlers because the seagrass fills and clogs the nets. Nevertheless, sparse deepwater seagrass habitat is potentially at risk from damage by trawlers.

Natural events such as cyclones and floods can cause widespread loss of seagrasses. Further, current agricultural land-use practices may

Seagrass beds provide habitat for important species such as dugongs and turtles.

exacerbate the effects of these natural events, as well as slow the recovery processes afterwards.

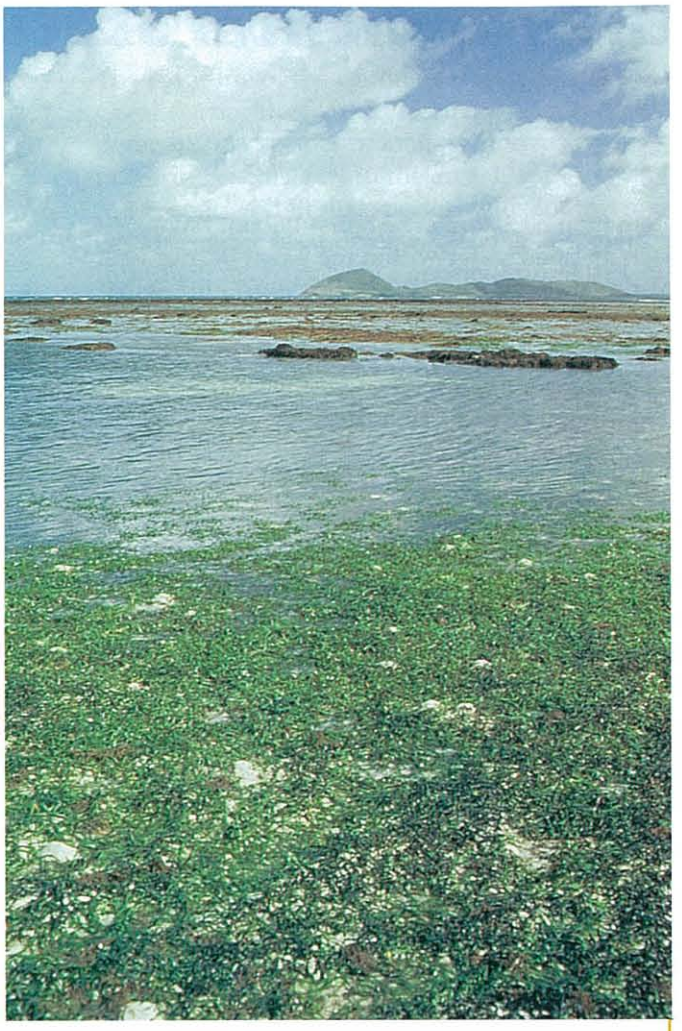
Overall, human pressures do not seem to have caused major decreases in areas of seagrass. However, this conclusion is drawn only from those areas where more than one seagrass habitat survey has been done (see *State*). Also, the survey methods used were not specifically designed to detect effects of human activity. Thus only very large impacts on seagrasses would have been detected by these surveys.

RESPONSE

Two separate systems exist to protect seagrass habitat from trawling: Great Barrier Reef Marine Park Authority zoning plans and Queensland Fisheries Management Authority coastal strip closures. Almost all coastal seagrasses north of Cape Tribulation are protected from trawling by these systems. Within the entire Marine Park approximately 45% of surveyed seagrass beds occur in areas where trawling is prohibited by the Marine Park zoning plans. The coastal strip closures protect an additional area of seagrass.

The Great Barrier Reef Marine Park Authority has recognised that seagrass habitat requires special protection because of its significance for threatened species and species of commercial and recreational importance, and its importance in primary production. When most early zoning plans for the Great Barrier Reef Marine Park were produced, seagrass habitat surveys had not yet been carried out. Thus it was not possible to zone areas based on direct knowledge of seagrass distribution. However, for more recent zoning plans, for example the current zoning plan for the Cairns Section and the proposed new zoning plan for the Far Northern Section, results of seagrass surveys have been available and used. In the zoning plan for the Cairns Section all known areas of coastal seagrass were zoned to afford protection from physical disturbance, including trawling. Similarly, in the proposed new zoning plan for the Far Northern Section, most shallow-water seagrass habitat is protected from trawling.

The Queensland Fisheries Management Authority, in consultation with the fishing industry, operates a system of coastal areas closed to trawling, known as coastal strip closures. The intention of these closures is to protect populations of juvenile prawns and associated seagrass habitat. Originally the boundaries of the coastal strip closures were determined using data from seagrass habitat surveys. However, these boundaries are regularly examined and sometimes moved. If trawlers begin to catch significant numbers of juvenile prawns in an area, then that area will be closed to protect those juveniles.



Seagrass meadows, shown here exposed at low tide, are important habitats in the World Heritage Area and continue to be surveyed.

One problem with protecting seagrass habitat with static management systems such as zoning plans is that, as discussed above, areas of seagrass habitat can change quickly. Care must be taken not to base management decisions on out-of-date information on seagrass distribution. Clearly, continued monitoring of distributions of seagrass habitat is crucial to provide information for management decisions. In addition, continued surveys will help us to understand how human activities impact upon seagrass

habitat. Research into seagrass distribution and biology is currently undertaken by the Queensland Department of Primary Industries, James Cook University's School of Tropical Environment Studies and Geography and the University of Queensland's Marine Botany Department.

Although much shallow-water seagrass habitat is protected through zoning and coastal strip closures, deepwater seagrass habitat does not yet receive such formal protection. Fortunately, dense meadows of deepwater seagrass are usually avoided by trawlers, because the seagrass clogs the nets. However, areas of lower density deepwater seagrass habitat are at risk of damage from trawlers. These lower density areas are known to be feeding grounds for dugongs, and are therefore important to the conservation of this endangered species.

The above protection measures protect seagrass habitat from direct impacts resulting from human activities in the vicinity of the habitat itself. Protection from indirect impacts resulting from land-based human activities is more difficult to achieve. Land-use practices and coastal management need continuing attention to minimise adverse impacts of increasing population and development. Integrated catchment management is crucial to the maintenance of seagrasses in the region. Further information on these issues can be found in *Environmental Status – Water Quality* and *Management Status – Water Quality and Coastal Development*.

SUMMARY

The Great Barrier Reef World Heritage Area has extensive and relatively well documented areas of coastal seagrass beds, which are an important habitat for several commercial species of fishes and prawn, and are an important food source for dugongs and green turtles. Deep seagrass beds further offshore also exist but their extent and importance for other organisms is not fully documented.

Many seagrass beds are protected from disturbance by trawling, however urban and agricultural development along the coast represent potential but poorly documented pressures. Deepwater seagrasses are not comprehensively protected from trawling, although these areas are avoided by fishers.

STATE

Reef macroalgae display a variety of growth forms including turfs, encrusting calcareous algae and the larger fleshy algae commonly referred to as seaweeds. They are a universal component of coral reef communities and play major ecological roles in food webs and reef growth. Macroalgae are able to rapidly colonise newly available substrate, both natural and man-made. Some groups of macroalgae appear to have negative roles during reef degradation from human impact.

The macroalgae of the World Heritage Area have high diversity and low endemism. The exact number of macroalgal species is unknown because of taxonomic uncertainty and limited geographical surveys, but 400–500 species are estimated to occur in the World Heritage Area. The red algae are the most diverse group. Brown algae are more abundant and diverse inshore, while green and red algae dominate on offshore reefs. More survey and taxonomic work is required to accurately describe these species and their distributions.

Under natural conditions, algal communities are highly variable showing latitudinal, cross-shelf and within-reef variation in composition and abundance. In addition to this spatial variability, many reef macroalgae are highly seasonal.

Inshore reefs usually have abundant and conspicuous macroalgal growth, in particular the tall brown fleshy alga *Sargassum*. Fleshy macroalgae also occur on offshore reefs where red algae are most common and *Sargassum* is virtually absent. The high abundance of *Sargassum* on inshore relative to offshore reefs has been attributed to isolation of inshore reefs from fish grazing pressure, rather than the direct enhancement of algal growth by higher nutrients in coastal waters. Algal turfs are widespread and abundant, and their cross-shelf distribution is influenced by fish grazing and water quality. Within a particular reef, the reef-flat and back-reef areas are often dominated by macroalgae.

It has been suggested that the abundance of macroalgae on inshore reefs is unnaturally high and is a sign of eutrophication and reef degradation, due to increased sediment and nutrient inputs from the land. However, in the absence of good historical data, it is still uncertain whether current abundances are natural or human-induced. While local increases in algal abundance have been reported on some reefs, there is no strong evidence as to whether macroalgal cover is generally increasing on fringing reefs.

Macroalgae are abundant in the deepwater, inter-reefal areas of the northern part of the World Heritage Area. Large mounds formed from the

Laurence McCook, Australian Institute of Marine Science

Macroalgae are abundant and conspicuous on inshore reefs.

green calcareous alga *Halimeda* cover up to 2 000 km^2 in this region and may be up to 20 m high. Some deepwater meadows of *Halimeda* are also found in the southern region. The World Heritage Area contains the most extensive actively calcifying *Halimeda* beds in the world.

PRESSURE

Macroalgal communities are affected by natural events such as cyclones, and pressures from human impacts such as land run-off and habitat disturbance. Under natural conditions, macroalgal vegetation can change rapidly in space and time (e.g. seasonal fluctuations) and this variability needs to be taken into account when collecting and analysing baseline information for historical comparisons. The effects of human activities, in particular changes in water quality, may delay or prevent the re-establishment of natural algal communities after disturbance.

The major impact on macroalgae derives from water quality changes as a result of land use and agricultural practices adjacent to the World Heritage Area. For more information on the processes involved, see *Environmental Status – Water Quality*. Increased sediment and nutrient loading in inshore waters can favour blooms of certain macroalgae, changing the composition of the natural algal flora and reducing the aesthetic value of the reef through replacement of coral by algal cover. From the limited research to date, it is not clear to what extent the current inshore algal flora is affected by land run-off.

The pressure that macroalgal blooms exert on other benthic organisms can be a direct or indirect consequence of changed water quality. Direct pressure comes from nutrient stimulation of macroalgal growth and indirect pressure from colonisation of space made available by the death of other organisms.

Fish grazing has a direct impact on macroalgal distribution and abundance. Fishing activities can disturb habitat and alter grazing pressure on algae. Trawling may directly affect deepwater inter-reefal macroalgae (see *Environmental Status – Inter-reefal and Lagoonal Benthos* for more details).

RESPONSE

Management related to macroalgae within the Great Barrier Reef Marine Park is carried out by the Great Barrier Reef Marine Park Authority. The impact of land run-off on macroalgae is being addressed through development of management actions minimising the effects of catchment use, agricultural practices and urban development on water quality. Further details on management actions to reduce run-off effects can be found in *Management Status – Water Quality and Coastal Development*. The importance of fish grazing in determining the cross-shelf distribution of macroalgae signals the need to protect herbivorous fish populations. For details on the management of the inter-reefal areas where extensive *Halimeda* beds occur, refer to *Environmental Status – Inter-reefal and Lagoonal Benthos*.

SUMMARY

Large fleshy algae occur on all reefs, but are more conspicuous on inshore reefs. The inter-reefal areas of the Great Barrier Reef World Heritage Area also contain the most extensive actively growing beds of *Halimeda* in the world. Despite concerns that algae may be taking over some inshore reefs, there is no strong evidence as to whether macroalgal cover is generally increasing on these reefs. However, monitoring data are sparse for macroalgae, and the relationship between algal cover and coral abundance is not clear. Consequently the management status and needs are uncertain.

STATE

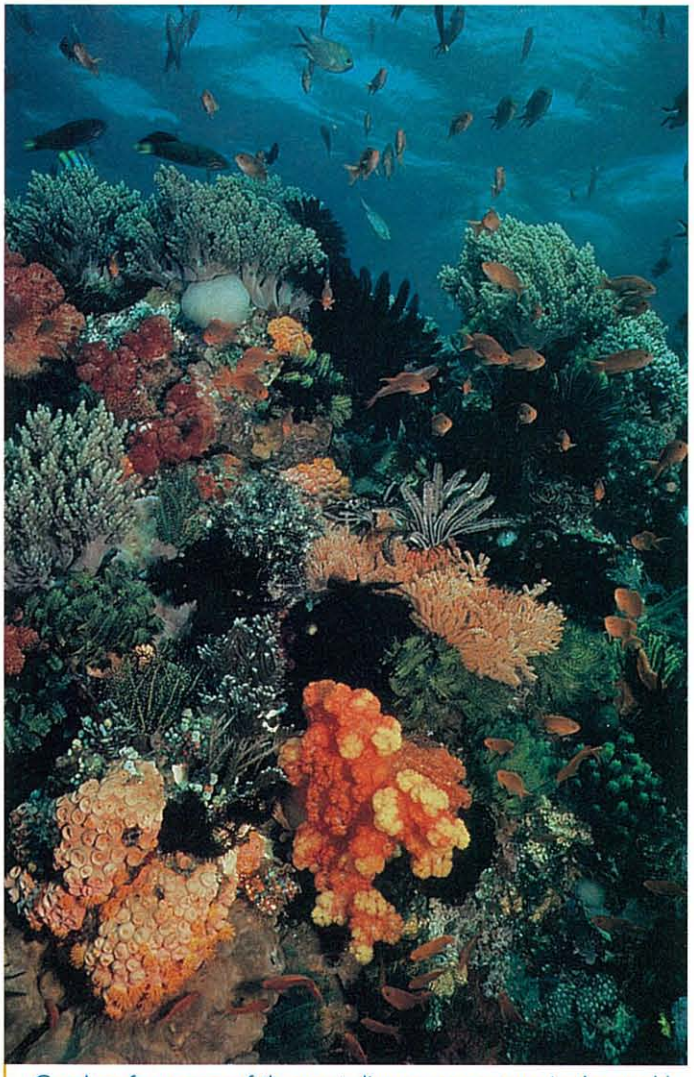
The Great Barrier Reef is part of a global centre of coral diversity located in the Indo-Pacific and possessing more than 70 hard coral genera. The Great Barrier Reef has some 350 individual species compared with a global maximum of about 450 species in Indonesian and Philippine waters. Most of the hard coral species on the Great Barrier Reef are also found in other reef areas, but 10 species are considered endemic, being found only on the Great Barrier Reef. The following account deals primarily with hard corals since this group has been the most comprehensively studied. Soft corals are also an important component of many reefs. Their taxonomy is not well documented and even less is known about their ecology and current status.

Spatial Distribution Patterns

Extensive surveys over the last two decades have demonstrated that corals (like fishes, sponges and macroalgae) show a marked change in species composition as one moves from sheltered inshore fringing reefs to the exposed shelf-edge reefs of the outer barrier in clear nutrient-poor water. Inshore reefs are often characterised by the relatively high abundance of non-*Acropora* corals such as *Galaxea*, *Montipora* and *Goniopora*, compared to mid-shelf reefs that have more plate-forming *Acropora* species, and outer-shelf reefs that are frequently dominated by digitate or sub-massive *Acropora* species.

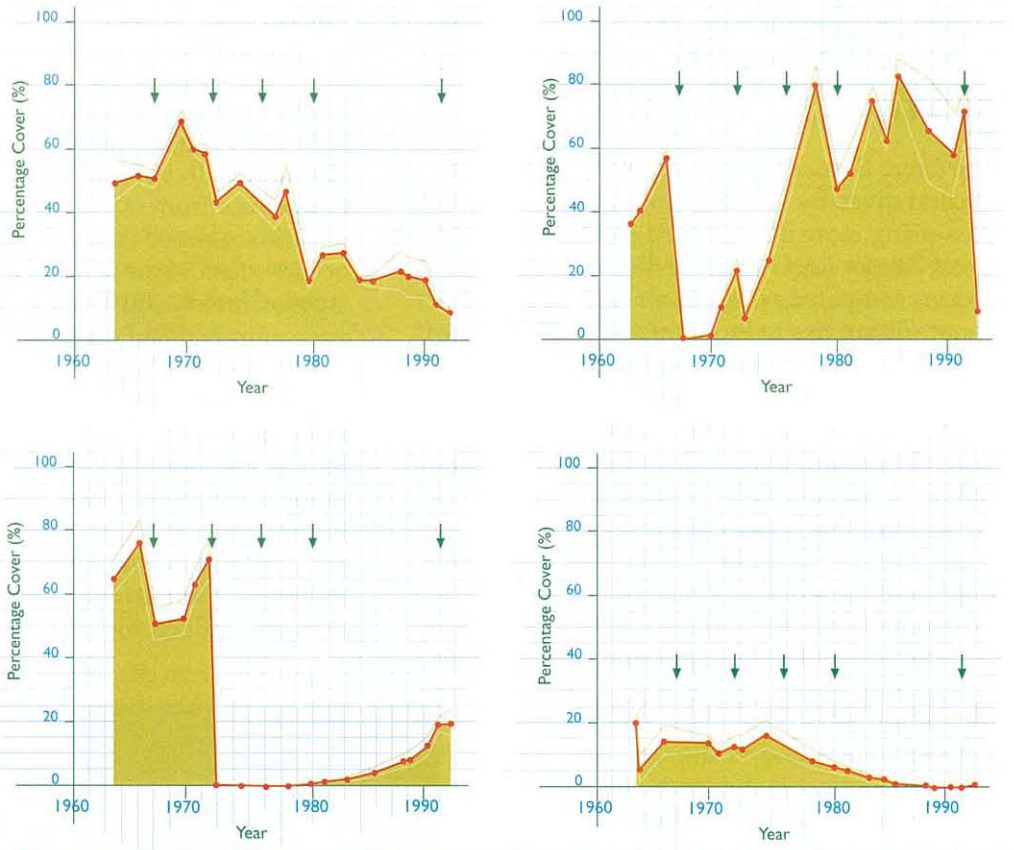
The cross-shelf pattern is correlated with an increase in wave exposure and light availability from inshore to offshore reefs. In terms of species diversity, the inner-most mainland fringing reefs or platform reefs within a few kilometres of the coast have the lowest diversity (100–150 species), but this rises rapidly away from the coast so that fringing reefs around high island groups such as the Palm Islands have over 300 species. Platform reefs further offshore in mid- and outer-shelf areas have high cover but somewhat lower species counts. Coral cover is extremely variable between reefs but surprisingly, highest cover is often found on nearshore reefs. However, this high cover can be set back to nearly zero by disturbances.

North–south variations in hard corals also exist but are less conspicuous than the cross-shelf differences. In particular, species diversity tends to decrease from north to south along the eastern Australian coast, although most of this variation occurs south of the World Heritage Area. Approximately 350 species exist in the northern and central Great Barrier Reef but only 244 are recorded in the Capricorn–Bunker reefs at the southern end of the Great Barrier Reef. The most recent large-scale monitoring survey of the Great Barrier Reef also indicates that the reefs sampled in the Capricorn–Bunker group had generally lower coral cover than other areas. This is possibly due to a disturbance event in the past, and there is some indication that corals on these reefs are undergoing recovery.



Coral reefs are one of the most diverse ecosystems in the world.

Changes in Coral Cover at Heron Island



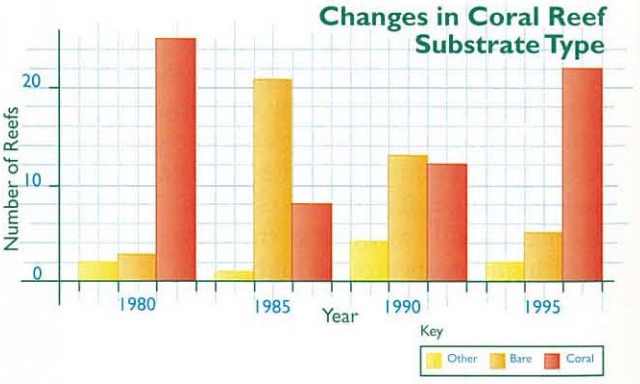
In a 30-year study of four different coral reef zones at Heron Island, coral cover was shown to vary by as much as 80%. Most of the declines in coral cover observed were due to cyclones, which are indicated by arrows. The upper and lower lines show the standard error, an indication of the uncertainty associated with the measurement.

Natural Variation

Although some systematic cross-shelf and north–south trends can be found among the reefs of the Great Barrier Reef, a striking feature is the natural variation which can exist between nearby reefs, and the variation which can occur over time on a single reef. Three separate long-term studies of corals have emphasised this variability through time. In one 30-year study on Heron Island in the southern Great Barrier Reef, coral cover was found to vary between 0 and 80% in different patterns depending on the site.

In another study covering six reefs in the central and northern Great Barrier Reef between 1980 and 1995, substantial changes occurred in terms of the numbers of areas dominated by corals, bare substrate or other organisms, but by the end of the study period, the proportions were similar to those at the beginning. However, this overall similarity in average conditions masked the fact that some reefs had improved while others had degraded during the period. At one inshore reef, an area once dominated by macroalgae was replaced by a coral dominated community.

A third, different type of long-term study has involved the analysis of coral density bands, which provide estimates of growth similar to that obtained from tree rings. This study has shown that while the short-term (5–10 year) record might lead one to believe that there has been a



Categorisation of 30 study areas according to dominant substrate type. Most sites were established in areas with high coral cover. By 1985, many had suffered coral mortality resulting mainly from predation by crown-of-thorns starfish or bleaching. By 1995, the overall relative abundance of sites in each category had returned to close to the 1980 situation, but many individual sites were markedly different to their 1980 state.

general decline in coral growth, a full analysis of the last 231 years indicates a series of repeated declines and recoveries of similar or even greater magnitude.

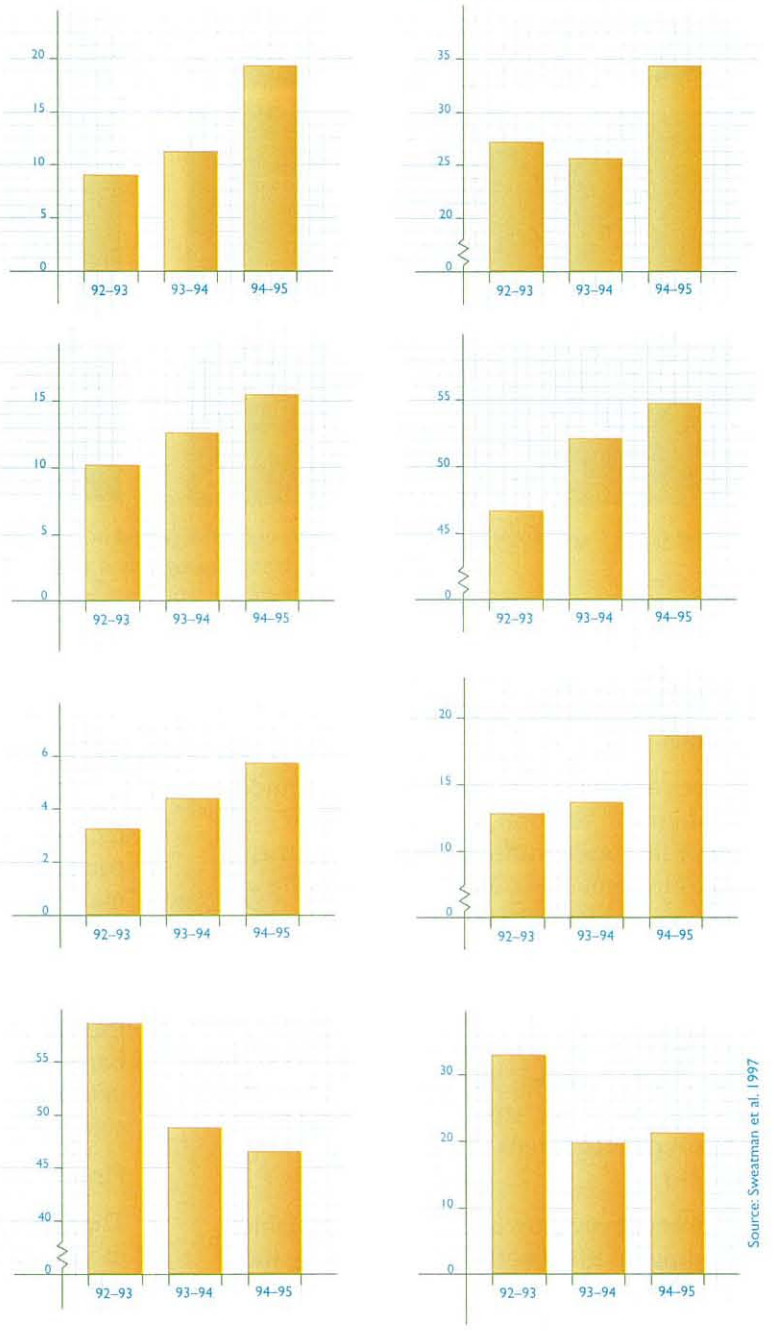
Overall, the long-term studies indicate that coral cover, coral growth and coral degradation can vary considerably over time in the absence of any direct human impacts. There is no clear evidence in any of these studies that there has been a major decline in coral status with increasing European influence in the region. Indeed two more recent monitoring programs (which cover a shorter period) suggest that most reefs have exhibited an increase in coral cover over the last three to ten years.

While these results are generally encouraging, it is important to note that there have been many anecdotal reports that corals in many areas of the Great Barrier Reef have declined in recent memory. It is difficult to verify such claims, but given the variety of human-induced pressures to which many reefs are or have been subjected, it is important not to be complacent.

One way to investigate possible cases of reef degradation over long time periods is through the comparison of historical photographs of the reef with contemporary scenes from the same location. A substantial survey of historical photographs undertaken by the Great Barrier Reef Marine Park Authority has indicated that out of 14 reefs investigated, six showed no obvious changes, four showed decreases in hard coral cover and four showed no obvious changes in some areas, but decreases in coral cover at others. While this study has demonstrated that some sites have undergone significant decline, the cause of this decline is not certain, and the mixture of results does not support the idea that there has been a systematic major decline in most reefs in the Great Barrier Reef.

Nonetheless, the monitoring studies reported here cover barely a fraction of the reefs in the Great Barrier Reef, and it is quite possible that serious but undocumented declines have indeed occurred in some areas.

Changes in Coral Cover on Selected Reefs

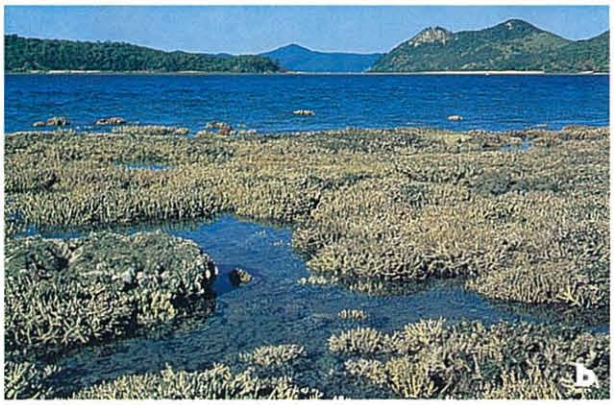


Source: Sweatman et al. 1997

Patterns of change in hard coral cover on eight different coral reefs in the Australian Institute of Marine Science Long-term Monitoring Program that showed significant change. Six of the eight reefs showed an increase in coral cover. Six other reefs surveyed at the same times did not show any significant linear change.

William Dakin 1950

William Saville-Kent 1893



This reef-flat at Daydream Island photographed around 1950 (a) and in 1995 (b) shows no significant change in coral cover; while the reef-flat at Stone Island photographed around 1890 (c) and in 1994 (d) shows substantial decline.

PRESSURE

Natural Events

Cyclones

Cyclones are one of the most common sources of natural impact on coral communities. For instance they account for virtually all of the declines in coral cover documented during a 30-year study of Heron Island corals. A recent compilation of cyclone data indicates that over the last 28 years there have been 135 cyclones in Queensland waters and that all areas of the Great Barrier Reef have been affected by at least one cyclone in this period. The reefs off Townsville have been particularly hard hit, having been within about 100 km of a cyclone 11 or more times.

The effects of cyclones are extremely variable, depending on the severity of the cyclone, the time spent in the vicinity of a reef, the orientation of the reef with respect to the wind and waves, and the depth of the corals. In extreme cases the reef can be denuded of all living corals and other benthic organisms, while in mild cases only the most fragile shallow corals are broken. On the same reef, one end can be denuded while the other is virtually undamaged.

If there are no subsequent disturbances, even severely affected reef areas (reduced to nearly zero per cent cover) are able to regain their original cover in about 20 years after the cyclone. However, if the original community possessed very old or slow growing corals, the time required to return to the same species and size composition could be substantially longer. Since many parts of the Reef experience more than one cyclone in 10–20 years, the reef can be considered as a mosaic of patches at different stages of recovery. Physical disturbance and recovery are therefore natural phenomena on the Great Barrier Reef and play an important part in determining the abundance and species composition of coral communities.

Floods

The Great Barrier Reef is located in the monsoonal tropics, and experiences distinct wet and dry seasons. During the summer wet season major rainfall events (some of which are associated with cyclones) can lead to extensive flooding of rivers and the discharge of millions of litres of sediment-laden freshwater into the coastal area. Depending on the wave, current and wind patterns, and the volume of discharge, the river plumes during flood events can extend for many kilometres offshore and impact nearshore and mid-shelf reefs.

Cyclones are common throughout the Great Barrier Reef World Heritage Area. They play an important role in determining the community structure of benthic organisms, including corals.

Ongoing research at the Cooperative Research Centre for Ecologically Sustainable Development of the Great Barrier Reef is examining the probability of different reefs being affected by river plumes at various intervals. In general, most nearshore reefs north of major river mouths experience lowered salinity and increased turbidity during flood events. Lowered salinity has been recorded up to 40 km off the coast in the central Great Barrier Reef, while visible flood plumes have been observed out to the Capricorn–Bunker reefs following the 1991 Fitzroy River flood.

The response of corals to flood plumes varies with the salinity and turbidity levels of the plume, and the duration of exposure. Substantial mortality can occur during extreme flood events. There was 85% mortality of shallow-water corals in the Keppel Islands following the Fitzroy flood.

Human Factors

Terrestrial influences from catchment use

While river flooding and flood plumes with low salinity and high turbidity are a natural feature of the coastal Great Barrier Reef region, the sediment load and associated pollutant load in these plumes may have increased in recent years as a result of adjacent land use. A desktop study has found that sediment and nutrient inputs to the Great Barrier Reef have increased fourfold since European settlement of the adjacent coast. A more detailed account of the nature of terrestrial run-off can be found in *Environmental Status – Water Quality.*

Both low salinity and high turbidity are known to stress corals and cause mortality in severe cases. In general, terrestrial run-off is considered to be one of the greatest potential threats to the Great Barrier Reef, however there are very little data to demonstrate that coral communities have been directly affected by this impact. As mentioned above many inshore coral reefs show consistently high levels of coral cover, and experience high frequencies of natural flood events. Nevertheless, some scientists feel that the Great Barrier Reef lagoon is showing signs of eutrophication and that decreases in coral cover on some reef areas are caused by this degradation. Macroalgal growth does increase when it is exposed to pulses of higher nutrients similar to those experienced during floods.

Anchoring

Anchoring by boats in coral reef areas is a cause of potentially major coral damage in heavily used areas. Anchors dropped onto areas of branching coral inevitably break at least some corals. Depending on the length and weight of anchor line used, and the strength and variability of the wind, the anchor chain can cause even more damage over a considerable area. While broken fragments are capable of regenerating, and recovery from a single anchoring event could occur within a year or two, repeated anchoring in the same area is clearly unsustainable.

Reports from local divers in the Whitsunday region have suggested that some popular

River plumes during flood events can extend for many kilometres offshore and can impact nearshore and mid-shelf reefs.

anchorages have been severely affected. High-use anchorages are clearly most likely to have suffered, but the absence of data on coral cover before and after the commencement of frequent anchoring makes it impossible to determine the extent and severity of this impact over the Great Barrier Reef. The use of moorings in all such sites over the next few years is expected to substantially reduce the problem (see *Response*).

Diving and snorkelling

Divers, snorkellers and reef walkers can break or abrade corals through intentional or unintentional contact. These impacts are likely to be highest at major tourist destinations such as Heron Island (reef walking) or around tourist pontoons (diving and snorkelling). Recent studies indicate that diver and snorkeller damage can be detected in high-use sites, but that the level of impact is generally low and the area of reef affected is small in proportion to the surrounding reef.

Construction and operation of tourist facilities

Corals can be damaged during activities associated with the construction of tourist facilities such as marinas and breakwaters, and the installation of piles for jetties. Although quite substantial areas have been affected in the past (e.g. construction of the Hamilton Island runway) most facilities are now preferentially located away from areas of good coral cover. For those structures which have been monitored for ongoing impacts after construction (breakwaters, jetties) no major adverse impacts on adjacent coral areas have been detected. In the case of tourist pontoons, the area directly under the pontoon is usually shaded to some extent and this has resulted in some coral death. Generally, tourist structures have a localised effect during construction, but are often subsequently colonised by corals during ongoing operation.

Stormwater run-off containing rubbish and pollutants, and sewage effluent are also potential impacts on coral reefs adjacent to tourist facilities. However, management regulations usually minimise these effects, and no major problems have been documented during monitoring of such facilities.

Pollution and shipping

Shipping can impact on corals through direct grounding of ships on reefs and through the loss of toxic cargo and fuel. Although there have been no major oil spills in the Great Barrier Reef World Heritage Area (and only one major spill in Torres Strait), 25 groundings and 19 collisions of ships have occurred in the last 22 years. Two recent groundings have been investigated in some detail and in both cases there has been localised mortality of corals crushed under the hull, but no obvious effects on surrounding areas. Information on management of shipping-related issues in the Great Barrier Reef World Heritage Area can be found in *Management Status – Shipping and Oil Spills*.

Dredging

Dredging of harbours and boat channels creates highly turbid sediment plumes that can kill corals up to hundreds of metres away. Most ports along the Queensland coast require periodic dredging after initial construction. Maintenance dredging at ports with nearby coral reefs is a potentially significant impact for these corals. In addition, construction of new marinas and boat channels is also occurring along the Great Barrier Reef coast.

There have been two major monitoring studies associated with dredging activities within the World Heritage Area. Both the Magnetic Quays monitoring program and the Townsville Port Authority Capital Dredging monitoring program indicated that, if the appropriate management protocols are put in place, it is possible for major dredging to take place without causing widespread coral mortality on adjacent coral reefs. While these results are encouraging it is important to note that each dredging event is likely to be different in the nature and pattern of potential impact. Therefore careful individual assessment, monitoring and management are required for all future projects.

Events of Uncertain Origin

Crown-of-thorns starfish

Crown-of-thorns starfish outbreaks have caused significant and extensive mortality of corals in the Great Barrier Reef on two previous occasions, and outbreaks are currently affecting reefs in the Lizard Island to Innisfail region. For more information on the crown-of-thorns starfish and its effects on corals, see *Environmental Status – Crown-of-thorns Starfish*.

There has been much debate about the cause of crown-of-thorns starfish outbreaks, and several theories have invoked human activities as an indirect cause. A recent survey of scientists however, suggests that most of them believe that crown-of-thorns starfish outbreaks are a natural phenomenon, although it is possible that the

frequency of outbreaks has increased due to some human influence. This possible increased frequency would cause affected reefs to be in a low coral, high algal state for longer periods.

Coral bleaching

Coral bleaching occurs when corals become stressed and eject the brownish coloured algae which live within their tissues. When this happens the white coral skeleton is visible through the clear coral tissue and the corals appear bleached white. Bleached corals are not dead and, if they are not severely stressed, they can regain their original algal densities and make a full recovery. However, many corals die during some bleaching events.

Bleaching has been formally documented on six occasions on the Great Barrier Reef with the earliest report in 1980 and the most recent event in 1998. Anecdotal reports suggest it may have occurred even earlier than 1980. During the 1998 event over 88% of inshore reefs exhibited some coral bleaching, with 25% of all inshore reefs having more than half of the corals affected. Although the level of mortality associated with the 1998 bleaching event has not yet been determined, up to 50% of the corals died on some reefs in a previous severe episode in 1982.

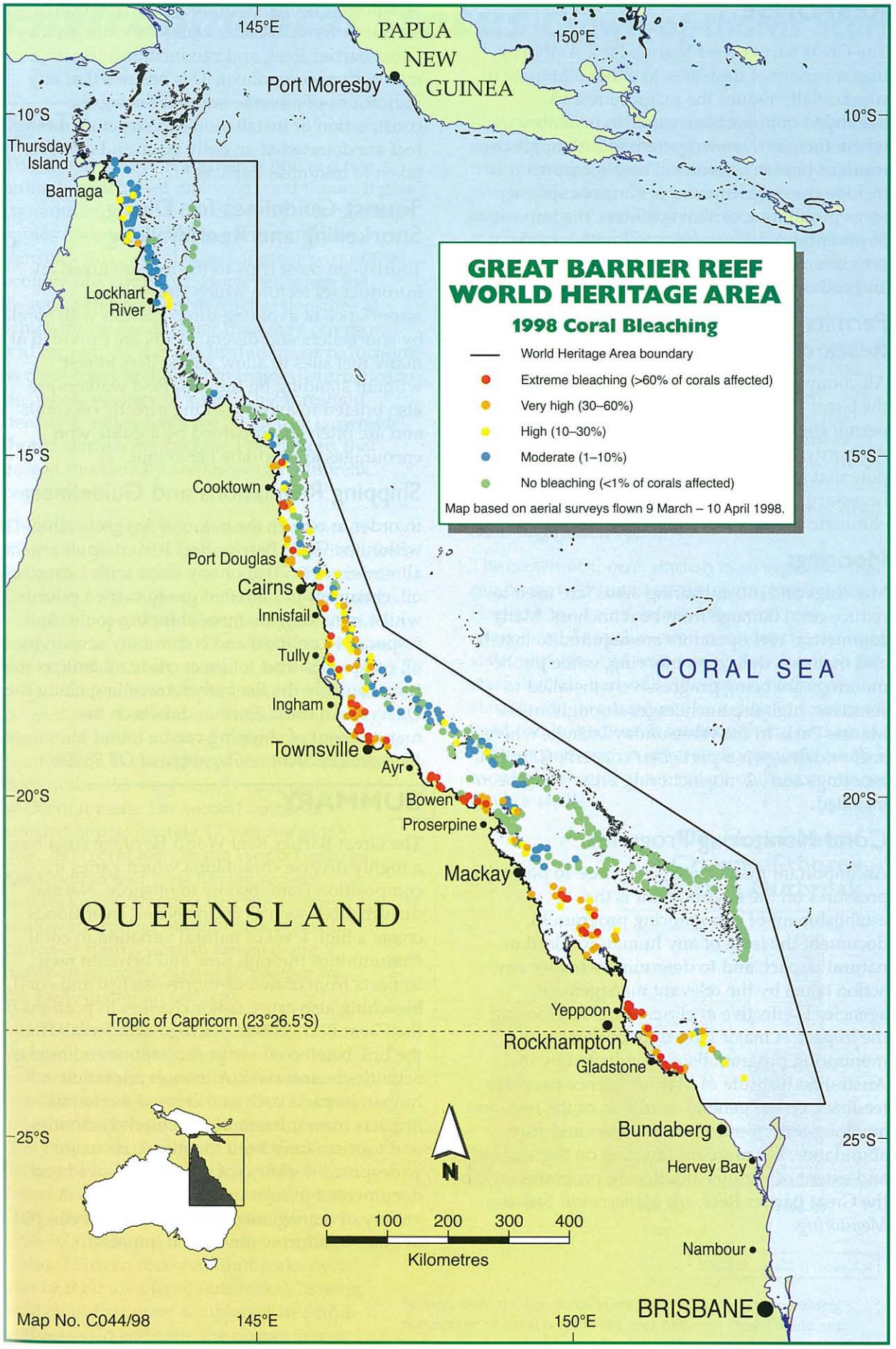
Generally coral bleaching affects inshore reefs most severely and is most common in shallow waters. In this respect it differs from the effects of crown-of-thorns starfish outbreaks, which tend to affect mid- and outer-shelf reefs and occur over a wide range of depths.

The principal cause of mass coral bleaching (involving a high proportion of corals on reefs spread over hundreds of kilometres) is believed to be elevated summer water temperatures. In addition, high levels of sunlight and lowered salinity are known to contribute to and exacerbate bleaching. Although there has been speculation regarding possible links between increased incidents of coral bleaching and greenhouse gas induced climate change, there is no clear scientific evidence for a link at this stage. Similarly, while convincing links between El Niño and coral bleaching have been made for bleaching events in some other countries, no clear relationship exists for bleaching on the Great Barrier Reef.

Coral disease

Although diseases are frequently reported as an important threat to corals in the Caribbean, only isolated reports of disease exist for the Great Barrier Reef. A variety of diseases and abnormalities are recorded as occurring on the Great Barrier Reef (e.g. black band disease, white band disease, coral tumours) but these do not seem to be affecting large areas of coral.

The main cause of mass coral bleaching is believed to be elevated summer water temperatures.


GREAT BARRIER REEF
WORLD HERITAGE AREA
1998 Coral Bleaching
World Heritage Area boundary
Extreme bleaching (>60% of corals affected)
Very high (30–60%)
High (10–30%)
Moderate (1–10%)
No bleaching (<1% of corals affected)
Map based on aerial surveys flown 9 March – 10 April 1998.
PAPUA NEW GUINEA
Port Moresby
Thursday Island
Bamaga
Lockhart River
Cooktown
Port Douglas
Cairns
Innisfail
Tully
Ingham
Townsville
Ayr
Bowen
Proserpine
Mackay
Yeppoon
Rockhampton
Gladstone
Bundaberg
Hervey Bay
Nambour
BRISBANE
CORAL SEA
QUEENSLAND
Tropic of Capricorn (23°26.5'S)
145°E
150°E
10°S
15°S
20°S
25°S
N
0 100 200 300 400
Kilometres
Map No. C044/98

RESPONSE

The Great Barrier Reef Marine Park Authority uses a variety of measures to either eliminate or substantially reduce the magnitude and likelihood of impacts on corals in instances where there is a known potential for impacts as a result of human activities. These measures include the establishment of zones or special areas prohibiting certain activities, the imposition of permit conditions associated with specific activities, and the establishment of guidelines and codes of conduct.

Permits for Commercial Activities and Research

All commercial and most research activities in the Great Barrier Reef Marine Park require a permit from the Great Barrier Reef Marine Park Authority. During the assessment of each permit, potential impacts on corals are considered and, if necessary, permit conditions are imposed to eliminate or minimise these impacts.

Moorings

Moorings and 'no anchoring areas' are used to reduce coral damage from boat anchors. Many commercial reef operators are required to install and maintain their own mooring, while public moorings are being progressively installed in sensitive, high-use anchorages throughout the Marine Park. In the Whitsunday Islands, where anchor damage is a particular concern, 60 public moorings and 12 'no anchoring areas' have been installed.

Coral Monitoring Programs

An important management response to potential pressures on the environment is the establishment of a monitoring program to document the level of any human-induced or natural impact, and to determine whether any action taken by the relevant management agencies is effective at eliminating or lessening the impact. A major long-term background monitoring program being conducted by the Australian Institute of Marine Science provides feedback on the general condition of the reef, and any long-term trends in coral cover and fish abundance. For more information on the scope and extent of various monitoring programs on the Great Barrier Reef, see *Management Status – Monitoring*.

Monitoring is often required as a condition of a permit to conduct commercial activities on the Great Barrier Reef, and can include a 'reactive monitoring' component. This ensures that any indications of adverse impacts during the construction or installation of a structure on the reef are detected at an early stage and action is taken to minimise impacts.

Tourist Guidelines for Diving, Snorkelling and Reef Walking

Tourists on most trips to the reef are given an introductory lecture which stresses the importance of avoiding direct contact with coral by snorkellers and divers. Floats are provided at many reef sites to allow snorkellers to rest without standing on the reef. Reef walkers are also briefed to avoid walking directly on corals and are often accompanied by a guide who encourages appropriate behaviour.

Shipping Regulations and Guidelines

In order to reduce the risk of ships grounding within the Great Barrier Reef it is compulsory for all vessels over 70 m or any ships with a cargo of oil, chemicals or liquefied gas to carry a pilot whilst transiting the inner shipping route. As a response to political and community sensitivity, oil companies tend to direct crude oil tankers to travel outside the Reef when travelling along the Queensland coast. Further details on the management of shipping can be found in *Management Status – Shipping and Oil Spills*.

SUMMARY

The Great Barrier Reef World Heritage Area has a highly diverse coral fauna which varies in composition from inshore to offshore. Natural disturbances such as cyclones and river floods create a high level of natural variation in coral communities through time and between reefs. Impacts from crown-of-thorns starfish and coral bleaching also cause major changes to portions of the Great Barrier Reef at irregular intervals, but the link between these perturbations and human activities is uncertain. Although important human impacts such as increased terrestrial impacts from urban and agricultural activities, and tourism have been identified, no major widespread declines in coral status have been documented in relation to these impacts. A variety of management measures have been put in place to address the known impacts.

STATE

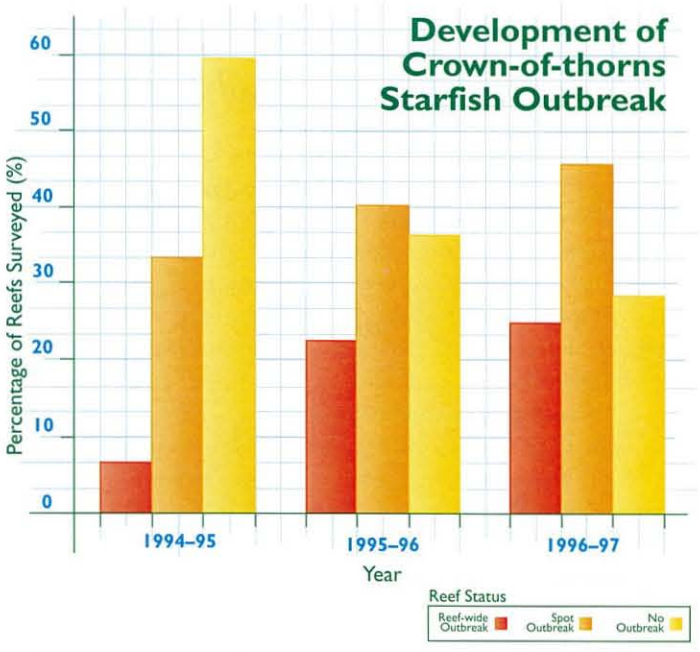
The crown-of-thorns starfish is one of a few animals which feed on living coral tissue. It gets its name from the dense covering of long sharp spines covering its upper surface. At low densities this animal is just another part of the ecology of a coral reef. However, when the crown-of-thorns starfish reaches densities at which it eats corals faster than they can grow and reproduce, this can lead to major reductions in coral cover and result in major disturbance to the whole ecology of a reef. This threshold density is estimated to be 30 mature crown-of-thorns starfish per hectare. Populations that exceed this density are known as 'outbreak populations'.

The first outbreak populations of crown-of-thorns starfish to be noticed and described were at Green Island and nearby reefs offshore from Cairns in 1962. A group of reefs experiencing outbreak populations simultaneously is known simply as an outbreak. Over the next 14 years this outbreak slowly spread southwards as far as reefs offshore from Mackay, where it gradually petered out. A second outbreak, probably again beginning to the north of Cairns and spreading southwards, occurred between 1979 and 1991. Both outbreaks were mostly confined to mid-shelf coral reefs. The second outbreak affected approximately 17% of the more than 2800 coral reefs in the World Heritage Area, with 5% of reefs having severe outbreaks. It is thought that the apparent southward spread of outbreaks is due to crown-of-thorns starfish larvae being transported from one reef to another by the East Australian Current.

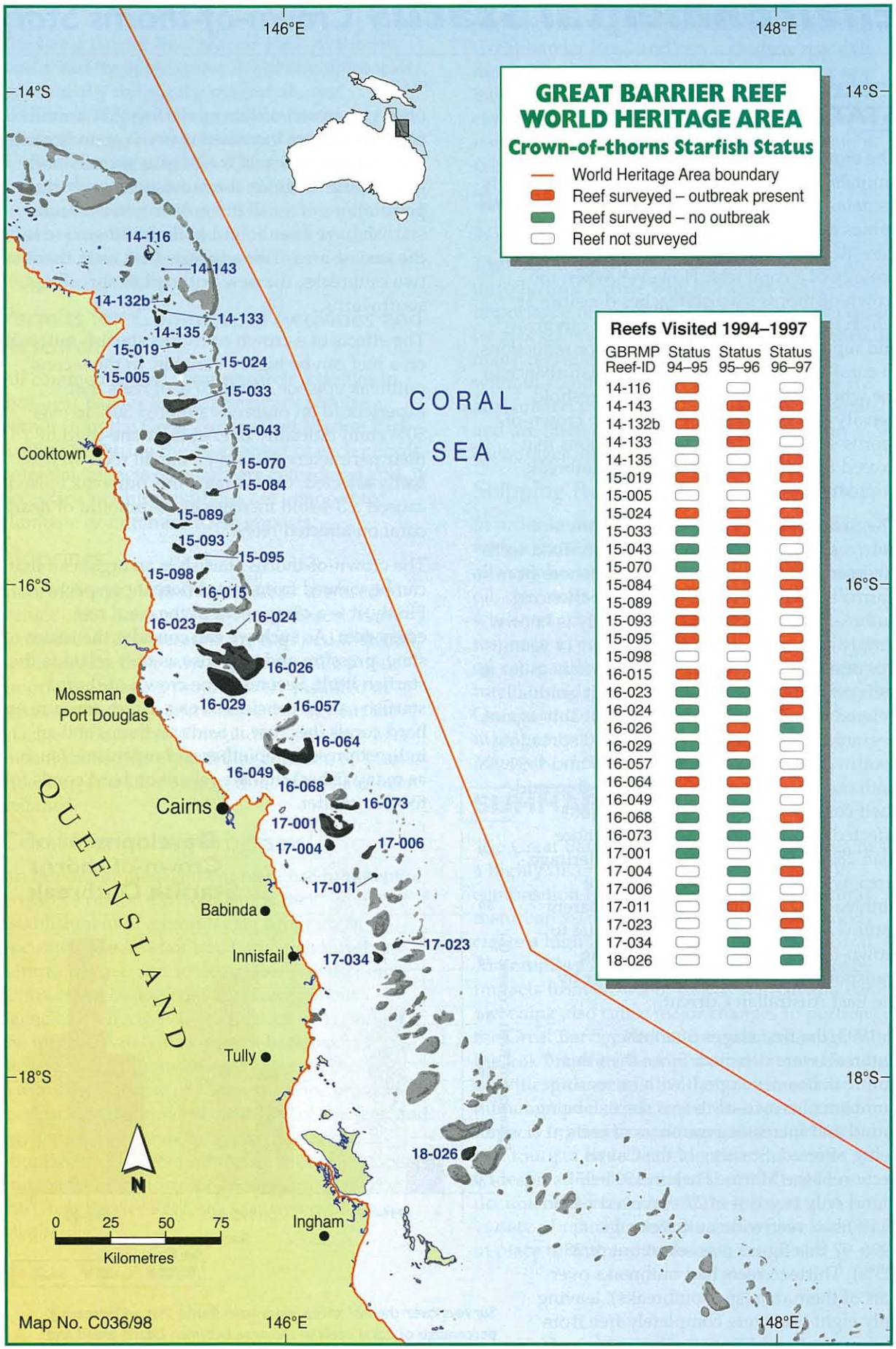
In 1993, the first stages of another outbreak were detected. Since then this outbreak has developed, with increasing numbers of crown-of-thorns starfish being found and increasing numbers of reefs being affected. Surveys of the Cairns Section of the Marine Park in 1994–95 found only two out of 27 surveyed reefs (7.4%) had reef-wide outbreaks. In 1996–97 this figure was seven out of 28 (25%). Thirteen reefs had outbreaks over part of their area (spot outbreaks), leaving only eight that were completely free from outbreaks. In addition, the proportion of observed crown-of-thorns starfish that were sexually mature increased every year, indicating that the outbreak will increase in severity and geographic range. In the most recent surveys, populations of small juvenile crown-of-thorns starfish have been found in the southern parts of the survey area. This suggests that, as in the first two outbreaks, the new outbreak is spreading southwards.

The effects of a crown-of-thorns starfish outbreak on a reef can be highly variable. In the second outbreak episode, about 57% of reefs that experienced an outbreak suffered 30% to over 50% coral mortality over at least one-third of their perimeters. However, not all reefs were so badly affected. On average, this outbreak episode caused a 3.4-fold increase in the amount of dead coral on affected reefs.

The crown-of-thorns starfish is an organism that can be viewed from two different perspectives. Firstly, it is a component of the coral reef ecosystem. As such we can consider the issues of state, pressure and response as they relate to the starfish itself. Secondly, the crown-of-thorns starfish can be considered as a direct pressure on hard corals (because it feeds on them) and an indirect pressure on other reef organisms (such as many fishes) that are reliant on hard corals for food or shelter.



Surveys over the last three years have found that an increasing percentage of coral reefs in the area between Lizard Island and Ingham are experiencing outbreaks of the crown-of-thorns starfish.



The current crown-of-thorns starfish outbreak is spreading southwards in a pattern similar to the previous two outbreaks. In this map, the categories 'reef-wide outbreak' and 'spot outbreak' are combined to form the category 'outbreak present'.

PRESSURE

Crown-of-thorns starfish outbreaks may be caused by the interaction of many factors, all of which may vary in both space and time. Despite significant research effort, there is still uncertainty as to the causes of crown-of-thorns starfish outbreaks.

It is possible that these outbreaks are a natural phenomenon. The crown-of-thorns starfish has the ability to produce very large numbers of offspring (a single large female can produce up to 60 million eggs in a breeding season), allowing populations to grow rapidly under favourable conditions. There is some geological evidence to suggest that outbreaks have occurred on the Great Barrier Reef for the last 3000 to 7000 years. However, as with most aspects of the crown-of-thorns starfish issue, this evidence is not unequivocal and there are those who disagree with the conclusions drawn from it.

Others have speculated that human activities may be responsible for at least making outbreaks worse and/or more frequent, if not actually causing them. Two major theories have been put forward as to how this may happen. Firstly, it is possible that increased nutrient run-off from the land increases the amount of phytoplankton in the water. Larval crown-of-thorns starfish feed on this phytoplankton and an increase in the food supply may lead to higher survivorship of the larvae, eventually leading to an outbreak. Secondly, it has been proposed that fishing and shell collecting have led to decreased numbers of predators of the crown-of-thorns starfish. Among these predators are the giant triton shell, the humphead maori wrasse and some emperors. The reduced numbers of these predators is thought by some to allow crown-of-thorns starfish populations to increase beyond natural levels.

Despite substantial research programs since 1972, none of the evidence gathered so far, either supporting outbreaks as natural phenomena or as being caused by human pressures, is unequivocal. A recent survey of scientists suggests that most believe that crown-of-thorns starfish outbreaks are natural phenomena, although it is possible that the frequency of outbreaks has increased due to some human influence. The causes of crown-of-thorns starfish outbreaks are complex and, so far, the role played by humans is unclear.

Each mature female crown-of-thorns starfish may produce up to 60 million eggs in a single spawning season.

RESPONSE

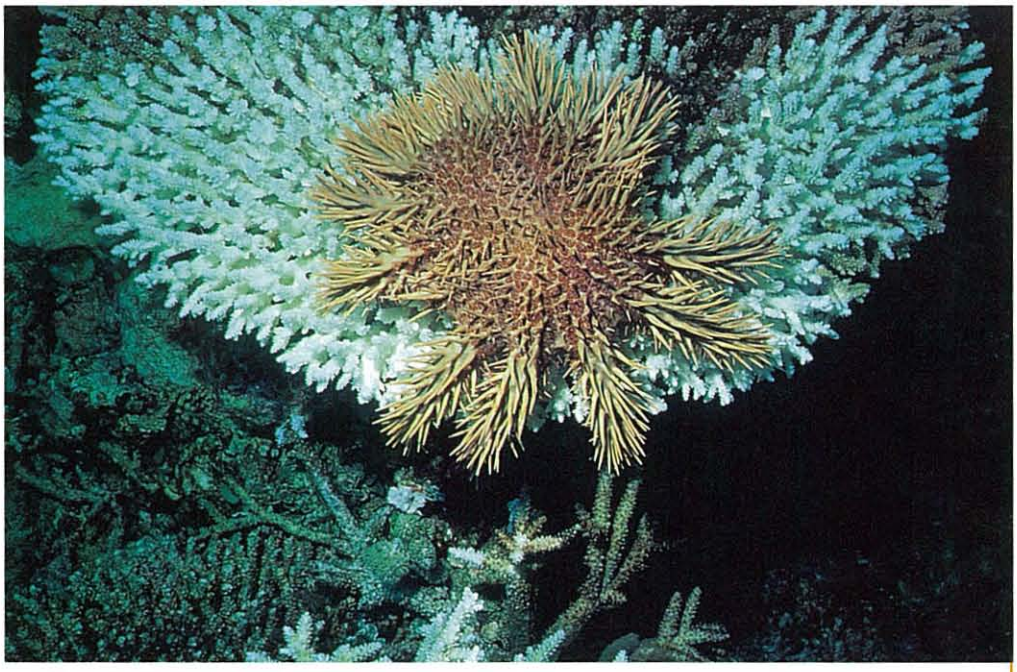
In the absence of definitive information about whether crown-of-thorns starfish outbreaks are natural, the Great Barrier Reef Marine Park Authority has adopted a policy of minimum intervention. This means that there is no interference with crown-of-thorns starfish populations on a large scale. However, small-scale control programs may be permitted by the Authority in areas of tourism or scientific importance threatened by crown-of-thorns starfish outbreaks. Sodium bisulphate (also known as 'dry acid') has been identified as an effective, environmentally acceptable agent to kill crown-of-thorns starfish on a local scale. It is biodegradable and does not affect other plants and animals on the reef. The chemical is applied by direct injection into the tissues of the crown-of-thorns starfish.

Because of the uncertainty about the causes of outbreaks, it is of vital importance that the waxing and waning of crown-of-thorns starfish populations and their effects on coral reefs are closely monitored. This may allow us to further understand whether or not these effects are sustainable in the long term. Currently, there are three major monitoring programs of crown-of-thorns starfish populations.

- Broadscale surveys are carried out by the Australian Institute of Marine Science using observers towed on manta boards. This method allows the detection of major crown-of-thorns starfish outbreaks and simultaneous observations of coral cover. These surveys have been carried out every year since 1985–86 on reefs spread throughout the World Heritage Area.
- Fine-scale surveys are carried out by the Cooperative Research Centre for Ecologically Sustainable Development of the Great Barrier Reef. These surveys use scuba divers to closely inspect the reef surface, allowing detection of much smaller sizes and numbers of crown-of-thorns starfish than the broadscale surveys. Fine-scale surveys have been carried out since 1994–95 and have only covered reefs in the Cairns and Central Sections of the Great Barrier Reef Marine Park.
- Observations from reef users are reported through the COTSWATCH program. This program operates anywhere in the World Heritage Area where users go. In 1993, it was the results from the COTSWATCH program that initially alerted scientists and managers to the build-up of crown-of-thorns starfish numbers in the Cairns Section.

SUMMARY

Crown-of-thorns starfish outbreaks can cause significant disturbance to coral reefs over a wide geographic area. At present, the Great Barrier Reef World Heritage Area is experiencing its third major outbreak, currently centred near Cairns and expected to progress southward in the next few years. Despite considerable scientific research, the cause of crown-of-thorns starfish outbreaks and the role of human activities as a causal factor are unknown. Consequently management activities are confined to accurately assessing the current extent and intensity of the outbreak, and to providing advice on crown-of-thorns starfish control measures for particular commercially and scientifically important sites.



Populations of the coral-eating crown-of-thorns starfish fluctuate from small numbers to major outbreaks that can cause substantial damage to reefs. Scientists are still uncertain as to what causes these outbreaks.

STATE

The Great Barrier Reef World Heritage Area is home to an amazing diversity of fishes. The exact number of fish species is unknown, but estimates range from 1200 to 2000, with 1500 being the most commonly quoted number. For the purposes of this report, fishes are divided into three groups: coral reef, inshore and estuarine, and pelagic. Much of the research that has been carried out on the fishes of the World Heritage Area has been on coral reefs, so there is more information available for fishes from this habitat than there is for fishes from others.

Coral Reef Fishes

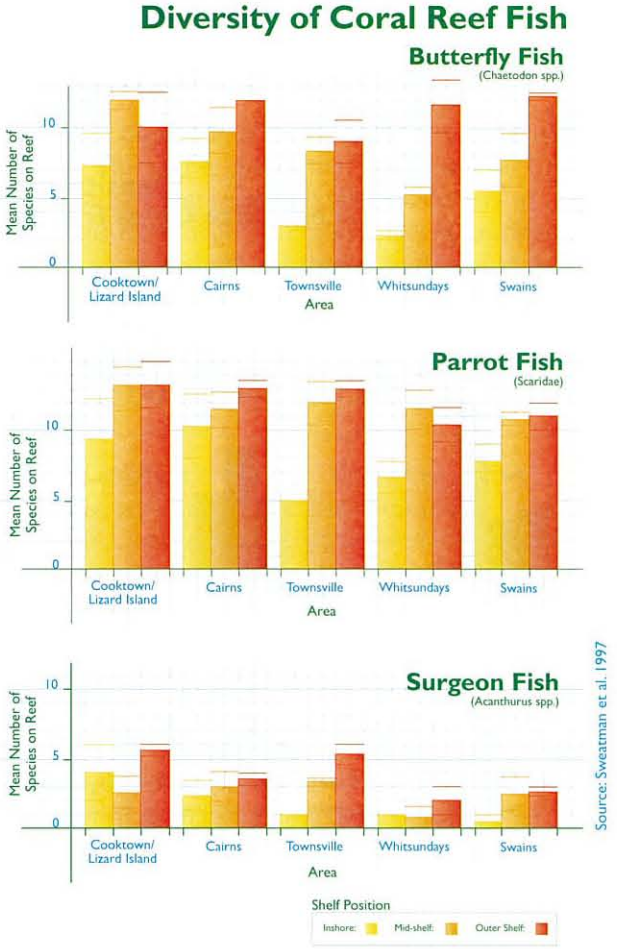
Broadscale studies of distribution of coral reef fishes have been carried out at the Australian Institute of Marine Science, particularly by the Long-term Monitoring Program. Findings indicate strong spatial patterns in distribution of fishes, particularly across the continental shelf. Scientists are uncertain as to what causes these patterns but several factors may be involved. They include:

- the degree of exposure to waters bearing high nutrient and sediment loads close to the mainland,
- the degree of exposure to waters bearing low nutrient and sediment loads and fish larvae from the Coral Sea, and
- the degree of exposure to wave action.

Latitudinal patterns are also present, but are weaker than cross-shelf patterns.

Many species of reef fishes are long-lived and recruitment of new juveniles to populations varies markedly from year to year. Thus, when a particular year has an unusually high recruitment event, that age-class can dominate the population. It is a feature of reef fish populations that they decline slowly over time, but increase rapidly after a good recruitment season. These slow declines and rapid increases are not synchronised between species because good recruitment seasons happen in different years for different species and may be widely separated.

For the most part, information about the state of species that are targeted by the reef fish line fishery (see *Pressure*) has been derived from studies comparing fished and unfished reefs or studying the effects of fishing.

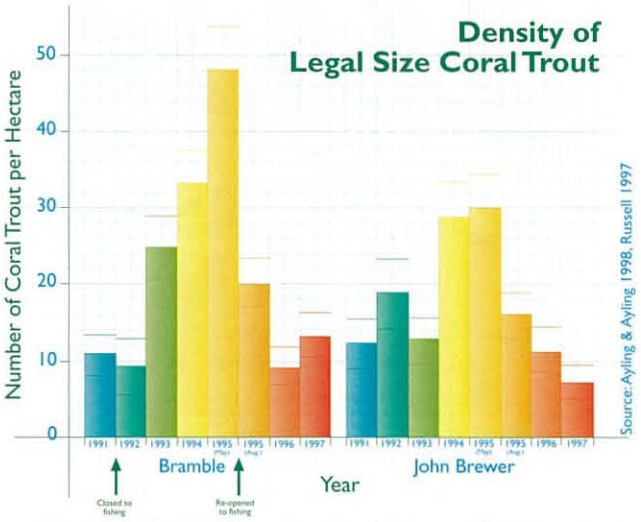


The diversity and community structure of most groups of coral reef fishes changes both with position across the continental shelf and with latitude. The lines above and below each bar show the standard error, an indication of the uncertainty associated with the measurement.

Studies of closed reefs that have been re-opened to fishing can show immediate effects of drastic reduction of numbers of legal size coral trout (one of the species targeted by the fishery – see *Pressure*). At Boult Reef, 75% of legal size coral trout were removed within 18 months after re-opening to fishing. When Bramble Reef was re-opened to fishing, the effects on the population of legal size coral trout were rapid with 57% of the legal size stock removed within two months and 78% within one year.

Juvenile recruitment pulses (as described above) can also dramatically affect the stock size on both closed and open reefs. During the closure of Bramble Reef, densities of legal size coral trout increased by over 300%. Increases, although smaller, also occurred on three nearby reefs that were open to fishing. These increases were driven

by a large pulse of juvenile recruitment in the first year of closure. As these juveniles grew, they increased the population of legal size coral trout in the following years on all reefs. However, as they reached legal size, they were vulnerable to being caught on the reefs open to fishing and numbers of legal size trout did not increase as much on the open reefs as they did on Bramble Reef.



After Bramble Reef was closed to fishing in 1992, the density of legal size (over 38 cm long) trout increased on both Bramble Reef and nearby John Brewer Reef, which remained open to fishing. This was due to a good recruitment season in 1992 on both reefs. However, the increase at Bramble Reef was greater than at reefs still open to fishing, because, as the recruits grew to legal size, they were fished at reefs other than Bramble. When Bramble Reef was re-opened to fishing in July 1995, the population of legal size coral trout fell by 57% in just two months. The lines above and below each bar show the standard error, an indication of the uncertainty associated with the measurement.

Most studies comparing nominally closed reefs with those open to fishing have failed to find significant differences in total numbers of coral trout. Findings in such studies may be affected by the history of fishing pressure, the strength of the age classes that are supporting the fishery and the amount of illegal fishing in protected areas. However, several surveys have found differences in the size structure of coral trout populations on open and closed reefs. Results indicate that open reefs often support higher numbers of below legal size coral trout and lower numbers of above legal size trout than closed reefs. These differences between open and closed reefs can be as much as twofold, as found in a study in the Capricorn–Bunker group in 1986.

A major problem with interpreting results from most studies that have compared open and closed reefs is that studies did not quantify the actual amount of fishing pressure on reefs. Reefs were simply classified as fished or unfished, according to their status in the zoning plan and results were analysed according to this classification. If nominally open reefs are only subject to low levels of fishing and/or nominally closed reefs are subject to illegal fishing pressure, then interpretation of these results is difficult. There is much anecdotal and some circumstantial evidence of illegal fishing on closed reefs, but no solid data about the true extent of such infringements. Further problems with interpreting such studies come from the apparent speed with which effects of fishing become apparent. As indicated by the studies at Boult and Bramble reefs, reductions in population numbers of targeted species on a previously unfished reef occur rapidly when the reef is opened to fishing. Thus, the major effects of line fishing over much of the Great Barrier Reef may have occurred before any scientific studies into those effects began.

Another important source of information about coral reef fishes targeted by the line fishery are the data from the compulsory commercial reef-line logbooks kept by the Queensland Fisheries Management Authority. Available catch, effort and catch per unit effort data are variable from year to year, but show no consistent trends at a regional scale. Two exceptions were most species groups in the Swains region and Spanish mackerel in the Townsville region. In the Swains, catch and catch per unit effort have been declining, subsequently followed by declining effort. Although catch and effort for Spanish mackerel have declined in the Townsville region, catch per unit effort has remained stable. Fishers indicate that this is a result of a swing to targeting coral trout for economic reasons. There is considerable anecdotal evidence of localised overfishing, particularly between Innisfail and Port Douglas. These views are shared by fishers from all fishing sectors but are not supported by the available scientific data.

Inshore and Estuarine Fishes

Relative to coral reef fishes, little information has been published about inshore and estuarine fish species. Present levels of commercial harvest are considered to be sustainable but the resource is considered to be fully utilised. A major information gap that has been identified is that relating to stock assessment of all exploited species. Another gap is the lack of information on recreational catch. While recreational catch rates are unknown, they are believed to be declining, particularly adjacent to population centres.

Pelagic Fishes

Pelagic fishes are those that typically are seldom, if at all, associated with the seabed. Instead, these fishes spend their lives in open waters. The degree to which individual species are associated with the seabed varies. Some species, such as Spanish mackerel, are often found close to coral reefs.

Pelagic fishes include a variety of mackerels, tunas, sharks, billfishes (including marlin and sailfish), wahoo, dolphinfish, herrings, trevallies, barracudas, anchovies, sprats, garfishes, scads, pilchards and sardines.

Information on the state of populations of pelagic fishes is scarce, even for those that are commercially exploited.

PRESSURE

Coral Reef Fishes

Direct human pressure on coral reef fishes comes almost exclusively from fishing. Fishing activities can be subdivided into four groups: commercial reef line fishing, recreational fishing (including line and spear fishing), charter boat fishing and aquarium fish collecting.

The commercial reef fish line fishery is a limited entry fishery with 251 licensed operators in the principal fishery, and a further 1563 licence holders with more limited access to reef fish stocks. Target species include trout, cods and groupers, tropical snappers and seaperch, emperors and wrasses. Catch and effort are recorded through a compulsory logbook system operated by the Queensland Fisheries Management Authority.

There are many issues of management concern in the reef fish line fishery. They include the live fish export sector, latent effort in the fishery and targeting of fish spawning aggregations. Additional information on the reef fish line fishery is presented in *Management Status – Fisheries*.

Over the last three years, commercial harvesting of live reef fishes has emerged as a new product form for reef fish stocks, in response to export market demand, principally from Hong Kong. However, more recently there has been a significant reduction in the live fish trade as a consequence of the downturn in the Asian economy. Prior to 1995, live fish production was negligible, but in 1997 it accounted for 15% of the total commercial catch of demersal reef fishes in Queensland.

Most of the catch in the live fish sector is coral trout. The higher prices that were paid for live fish caused some commercial line fishers to convert from dead-fish to live-fish operations. Also, some inshore net fishers moved into the live reef fish sector. About 110 licensed fishing boats changed over to live fish operations during the peak of demand for live fish. These boats produced an annual export income of about $20 million.

There is latent effort (also known as excess fishing capacity) within the commercial fishing sector. Latent effort is that which is licensed or permitted but not currently taking place or not fully utilised. It means that fishing effort can potentially increase without management arrangements changing or new licences being issued.

Some reef fishes form dense spawning aggregations at particular sites and times. Evidence from elsewhere demonstrates that fishing targeted at spawning aggregations has the potential to seriously jeopardise the viability

The Great Barrier Reef is home to an amazing diversity of fishes with estimates ranging from 1200–2000 species.

of stocks. In the Great Barrier Reef, scientists have documented small spawning aggregations of common coral trout and there is anecdotal evidence of larger aggregations of other species targeted by the reef fish line fishery. The potential to overfish stocks due to increased fishing effort during fish spawning seasons has been identified as an issue that needs to be addressed by fishery managers, researchers and the various fishing sectors. However, there is virtually no good information available about the extent to which spawning aggregations are targeted, or what effect this targeting is having.

Recreational fishing includes line and spear fishing. Results of a Queensland Fisheries Management Authority telephone survey in October 1996 indicated that about 35% of people living on the coast adjacent to the Great Barrier Reef fish for recreation. Of these, between 30 and 35% (depending on the area) target saltwater species such as coral trout, mackerel, whiting and barramundi. Only limited information is available on catch and effort, but estimates indicate an annual catch of 3500–4300 tonnes (mostly from line fishing in coastal and reef waters).

In 1998, the charter boat fishery comprised 270 charter vessel operators holding permits to undertake fishing trips. Of these operators, 211 were authorised to engage in offshore fishing. In 1996–97, charter boat operators generated 15 633 days of fishing effort and caught 265 tonnes of fishes, mostly coral trout, red emperor and red-throat emperor.

Current information about stocks of reef fishes is insufficient to demonstrate whether or not current levels of exploitation are sustainable. For information on the harvest fishery for marine aquarium fish, see *Management Status – Fisheries*.

Inshore and Estuarine Fishes

Inshore and estuarine fish stocks are exploited by commercial, recreational, charter boat and indigenous fishers, as well as fishing guides. The main species groups exploited include mullet, bream, whiting, lesser mackerel, salmons, barramundi and sharks. Total commercial catch is approximately 3000 tonnes per year with an estimated value of $15 million.

Currently, there are 814 net endorsements issued to commercial fishers on the east coast. It is estimated that 40 to 50% of these operate in the World Heritage Area. There are approximately 200 licensed charter boat operators and fishing guides. Their effort adjacent to population centres and tourist destinations is considered significant.

There are some issues of management concern in the fishery for inshore and estuarine fishes. For commercial netting, the major issues are the bycatch of non-target species and the incidental capture of protected or endangered species such as turtles, dugongs and dolphins. Another concern is the effects of net fishing on the biodiversity of coastal and estuarine systems.

Pelagic Fishes

Both recreational and commercial fishers fish certain species of pelagic fishes.

Small, inshore pelagic species include anchovies and sprats. No fisheries currently exist for this group of fishes within the World Heritage Area, but potential for industrial fisheries for baitfish has been shown to exist, often close to coral reefs.

Small, open-water pelagic species include garfish, scads, pilchards, sardines and herrings. They are either fished commercially as baitfish (especially garfish) or have considerable potential as baitfish for commercial longline fishing in the Coral Sea, recreational marlin or sailfish fishing, and perhaps for cat food, mariculture or human consumption.

Large, coastal pelagic species are subject to commercial and recreational fishing pressure, usually by trolling. These species include Spanish mackerel, double-lined mackerels, some tunas, trevallies and barracudas. Commercial fishing using drift mesh nets takes a number of shark species in the whaler family and a variety of inshore mackerels. Between 1988 and 1993, the catch of sharks on the east coast of Queensland was between 320 and 450 tonnes. Between 60 and 95% of this catch was reported from within the World Heritage Area. Little has been documented about the species composition of the catch.

Large, oceanic pelagic species include tunas and billfishes. There is a commercial fishery for tuna, but the fishers rarely enter, or even come close to, the World Heritage Area. The tuna fishers have a voluntary ban on keeping any billfishes that are caught. The recreational fishery for billfishes is mostly restricted to the continental shelf, inside the World Heritage Area. This sector has a voluntary code of practice of non-retention of black marlin, except first marlin in some cases or potential record weight fish. The majority of marlin caught are released and some are tagged before release.

RESPONSE

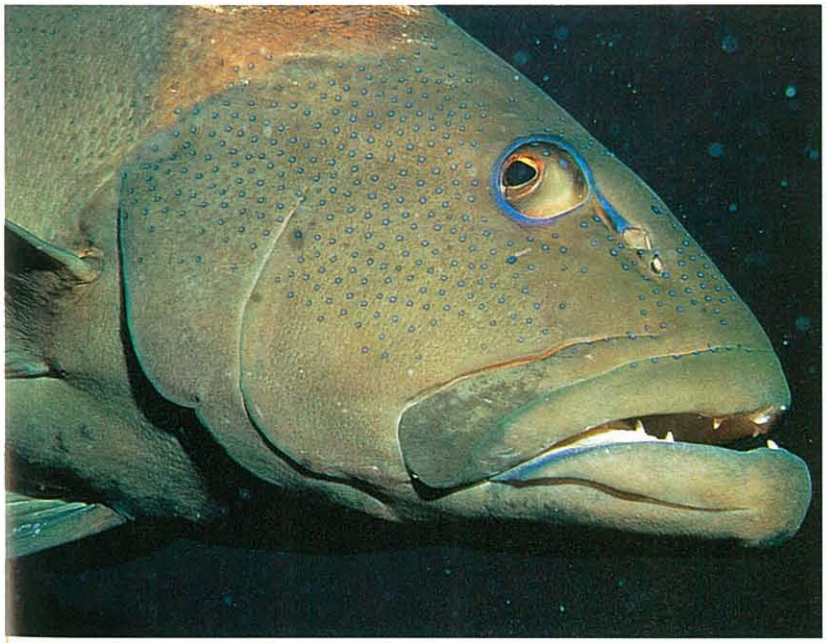
Management related to fishes is carried out mainly by the Queensland Fisheries Management Authority and the Great Barrier Reef Marine Park Authority. Common to both of these agencies are the principles of conservation, ecologically sustainable use, protection of critical areas, equitable resource use and integrated management. However, these two organisations have separate responsibilities. The Great Barrier Reef Marine Park Authority is primarily responsible for the care and development of the Great Barrier Reef Marine Park and is not responsible for fisheries management, except for this purpose. The Queensland Fisheries Management Authority is responsible for the management of fishing and collecting operations and optimisation of the use of available fisheries resources. Further details of the management activities of these two agencies can be found in *Management Status – Fisheries*. The Australian Fisheries Management Authority is responsible for management of fisheries for some pelagic species within the World Heritage Area.

Coral Reef Fishes

Under the current fishery management regime of the Queensland Fisheries Management Authority, commercial line fishing is managed through licensing, gear restrictions and minimum size limits on the major species. Bag limits apply to the recreational fishing sector, while charter boat fishing is managed through licensing and bag limits. Certain reefs are protected from fishing through Marine Park zoning. Under the zoning plans, there is no distinction between commercial and recreational operations in the reef fish line fishery.

A review of the management measures for the reef fish line fishery is nearing completion. Management issues of concern such as latent effort and emerging new fishing effort are being considered by the Reef Fish Management Advisory Committee. New management measures for the fishery will be implemented by statutory fishery management plans.

Management of the reef line fishery has been hampered by a shortage of information about the effects of fishing. The Effects of Line Fishing project has been established to provide the necessary technical basis for quantitative evaluations of potential management strategies for line fishing in the Great Barrier Reef World Heritage Area. The project is a joint initiative of James Cook University, the Australian Institute of Marine Science, the Queensland Department of Primary Industries, the Marine Division of the Commonwealth Scientific and Industrial Research Organisation and the Great Barrier Reef Marine Park Authority. The Effects of Line Fishing Experiment is one strategy of the project to gain necessary data as quickly as possible. The first phase of the experiment involved the opening of previously closed reefs to fishing and the closure of historically open reefs to assess the impact on reef fish stocks and reef communities of recreational and commercial fishing, and the recovery of reef fish populations after fishing ceases.



The coral trout is the fish most sought after by both recreational and commercial fishers.

Inshore and Estuarine Fishes

The Queensland Fisheries Management Authority uses a number of restrictions in the management of the fishery for inshore and estuarine fish species:

- limited entry (in early 1998, a licence buy-back operation resulted in a reduction in the number of east coast commercial net endorsements from 1029 to 814),
- limitations on length, drop, mesh size and line strength of commercial nets,
- limitations to vessel upgrade and replacement,

- spatial and temporal closures aimed at protecting juvenile and breeding stocks and reducing conflict among fishing sectors,
- minimum and maximum legal sizes of fish,
- bag limits for some species for recreational and charter boat fishers,
- gear restrictions for recreational and charter boat fishers, and
- a licensing scheme for charter boat operators and fishing guides.

As with other fisheries in Queensland, there is a Management Advisory Committee for estuarine and inshore fisheries. The Tropical Finfish Management Advisory Committee is an expertise-based group which is currently preparing a discussion paper on the fishery, as a first step in the production of a management plan. Further reductions in licence numbers are intended as a part of the management plan.

Pelagic Fishes

Some pelagic fishes, including many of the larger coastal species, have migratory adults or use different habitats at different phases of the life cycle. Thus, for some species, individuals spend part of their lives inside the World Heritage Area and part outside. This can complicate management of these species.

Tuna, some tuna-like species and billfishes fall under the responsibility of the Commonwealth organisation, the Australian Fisheries Management Authority. Within the World Heritage Area, pelagic fishing operations are limited to line gear of no more than six hooks. Therefore, commercial fishing activities are restricted to trolling, pole-and-line, handline and very short horizontal or vertical longlines. The majority of commercial pelagic fishers rarely enter, or even come close to, the World Heritage Area.

A number of pelagic fish species are the responsibility of the Queensland Fisheries Management Authority. Trevallies, wahoo and reef-associated mackerels such as Spanish and double-lined mackerels are considered by the Reef Fish Management Advisory Committee. These species are primarily taken by hook and line. For the east coast stock of Spanish mackerel within the World Heritage Area, there is a minimum legal size and a bag limit for the recreational sector. Targeted mesh netting is banned to prevent netting on major identified spawning areas.

The remaining mackerels and sharks are, for commercial purposes, taken primarily by mesh nets. Therefore they are considered by the Tropical Finfish Management Advisory Committee. Regulations exist for net length and mesh size. There are legal size restrictions for the mackerel species and a bag limit for recreational fishers.

For small pelagic species, the Queensland Fisheries Management Authority has regulations about small mesh surround nets deployed for garfishes, and gear restrictions banning the use of purse seine nets or lift nets.

SUMMARY

There are approximately 1500 species of fishes in the Great Barrier Reef World Heritage Area. Community composition varies across the shelf with some species being restricted almost exclusively to inshore or shelf-edge reefs. Reef fish numbers vary considerably from reef to reef and from year to year as a result of fluctuations in recruitment.

Line fishing pressure represents the most important pressure on reef fishes, and several studies have detected differences between fished and unfished populations and between periods before and after the re-opening of a closed reef. While larger fishes tend to be more abundant on unfished reefs, there is no indication from various monitoring programs of any large-scale significant declines in targeted species. Line fishing is controlled through limited licensing of commercial operators, limitations to fishing gear, bag limits, size limits, seasonal closures and the zoning of selected reefs to prohibit fishing. Uncertainties regarding the effectiveness of reef closures due to illegal fishing in protected areas, the lack of data on long-term trends, and the need to protect spawning aggregations are issues which require further attention.

Fisheries also exist for some species of inshore and estuarine fishes, and pelagic fishes in the World Heritage Area. Even for commercially exploited species, stock assessments and trend data are very limited. Fishing is controlled by a variety of management measures including licensing, gear restrictions, size and bag limits, and spatial and seasonal closures.

Environmental Status | Birds

The bird species of the Great Barrier Reef World Heritage Area can be divided into three groups based primarily on habitat use: shorebirds, land birds and seabirds. There are seven internationally significant areas for shorebirds in or adjacent to the World Heritage Area, including Bowling Green Bay and Shoalwater Bay. The land birds of the World Heritage Area are found on continental islands and the communities on these islands are similar to those of similar habitats on the adjacent mainland. However, the World Heritage Area is particularly important to a number of land birds, including the Torresian imperial-pigeon and the silver-eye.

Most of the detailed information available about birds in the World Heritage Area concerns seabirds and the rest of this section will deal exclusively with this group.

STATE

Between 1.4 and 1.7 million seabirds from 22 species breed on islands in the World Heritage Area each year. The population of non-breeding birds may add a further 425 000, giving a total seabird population that may exceed two million. This represents more than 25% of Australia's tropical seabird breeding population.

By far the two most numerous species are the wedge-tailed shearwater and the black noddy. More than 50% of Australia's black noddy population and about 25% of its wedge-tailed shearwaters breed in the World Heritage Area.

Breeding populations of seabirds are concentrated in the northern and southern quarters of the World Heritage Area where islands suitable for nesting are most common. At least 55 islands have been identified as significant seabird nesting sites. In particular, the 12 islands of the Capricorn–Bunker group, in the extreme south, support 73–75% of the total seabird biomass of the World Heritage Area, mainly because the wedge-tailed shearwater and black noddy are found in this area. However, it is the northern part of the World Heritage Area that is home to the greatest seabird diversity with 22 breeding species (in other words all the species found in the World Heritage Area). Raine Island, in the north, has the greatest diversity of any island with 15 breeding species.

Seabird populations on islands are highly variable, even under natural conditions. Thus, in order to positively identify trends in populations, intensive monitoring is required. One seabird study that has positively identified population trends in the Great Barrier Reef involved monthly bird censuses over a ten-year period at Michaelmas Cay. The study identified a 46% decrease in the number of nesting pairs of common noddy between 1984 and 1994 and a 26% decline in the sooty tern population. Another study from the Swain Reefs has shown significant declines in numbers of brown boobies and silver gulls, but stable numbers of masked boobies. Brown booby numbers fell from 3200 in 1986 to 1300 in 1993. Only this kind of high intensity, long-term monitoring can hope to detect trends in seabird populations.

PRESSURE

Seabird populations are affected both by natural pressures and by pressures from human activities. There have been no studies into the relative effects of natural and human pressures. However, it seems likely that effects of human activities may delay recovery of populations from natural disturbance or even prevent the recovery altogether.

Natural pressures on seabird populations include cyclones and gales, scarcity of food during El Niño events and habitat loss from island erosion. For example, reduction in food availability,

Several species of seabird, such as this black noddy, nest on islands in the Great Barrier Reef World Heritage Area.

probably associated with El Niño, is the most likely cause of the declines in brown booby and silver gull numbers in the Swain Reefs.

Cyclones in 1986 and 1990 at Michaelmas Cay caused short-term reductions in the breeding population of common noddies by 34% and 47% respectively. The most likely explanation for these reductions is not mortality of birds but simply that birds stayed away from the island during and immediately after the cyclones. In addition, the cyclones did not affect all species equally, with no decline in the numbers of sooty and crested terns.

More recently, in 1997 cyclone Justin hit Michaelmas Cay, causing an estimated two-thirds of the seabird population to be displaced and 80% of the island's vegetation to be buried under sand. Most of the seabirds returned after the cyclone moved away. Although, in the examples described above, there was apparently little bird mortality as a result of cyclonic activity, this is not always the case. If a cyclone or inclement weather prevents breeding adults from feeding their chicks, this can lead to high mortality of chicks from starvation.

Pressures caused by human activities include direct disturbance of nesting seabirds and habitat loss and deterioration. Direct disturbance is of particular concern on islands with high levels of tourism activity.

The cause of the long-term decline in populations of common noddies and sooty terns at Michaelmas Cay described above is uncertain. However, the most likely cause of the decline is increased human activity due to tourism on the island, with visitation in the early 1990s exceeding 70 000 people per year.

RESPONSE

The management of most islands in the Great Barrier Reef World Heritage Area, including those with nesting seabird populations, is the responsibility of the Queensland Department of Environment and Heritage. Access to these islands ranges from completely prohibited without a scientific research permit to completely open. Some islands have seasonal closures to protect seabirds during the breeding season. Guidelines for managing visitation to seabird breeding islands have been published by the Great Barrier Reef Marine Park Authority.

The greatest challenge in making management decisions affecting seabirds is to increase understanding of their populations and status. The annual monitoring of seabird breeding numbers at key locations and regions should continue in order to further document populations trends. Studies of this nature are required to improve understanding of the seabird populations of the Great Barrier Reef World Heritage Area and provide for informed management decisions.

Michaelmas Cay provides an example of how monitoring data can assist in management decision making. As a result of concern over the effects of cyclone Justin, access to the cay was closed for two weeks by the Queensland Department of Environment and Heritage. Long-term declines in sooty tern and common noddy populations led the Department and the tourism industry to jointly develop new management arrangements. Human use of the cay was reduced by restricting the area for human access to 50 m wide (previously 75 m) and below the 3 m tidal limit (previously 4 m). The number of people allowed on the cay at one time was also reduced from 100 to 50. These new measures have been put in place for a four-year period.

In addition to the new management measures, a Michaelmas Cay Steering Committee was formed to review issues of relevance to the management of the cay. This Committee comprises representatives from the Queensland Department of Environment and Heritage, the tourism industry, conservation groups and Birds Australia. Monthly counts of seabird populations on the cay are continuing to monitor the effects of the new management measures.

SUMMARY

The Great Barrier Reef World Heritage Area is an important habitat for breeding seabirds, containing more than 25% of Australia's tropical breeding populations and over 50% of the population of one species. The northern and southern quarters of the World Heritage Area are the most important for breeding seabirds due to the abundance of suitable islands for nesting.

The high level of natural variability in seabird numbers necessitates a high frequency of monitoring in order to detect trends. Declines in some species have been observed. In one location this has been attributed to tourism activities, whilst in another it may be associated with El Niño. Management to protect seabirds has focused on restricting access to breeding areas and ongoing status monitoring. Guidelines for managing visitation to seabird breeding islands have been developed.

The reptiles found in the waters of the Great Barrier Reef World Heritage Area fall into three major groups: crocodiles, marine turtles and sea snakes.

Crocodiles found in the World Heritage Area are considered temporary migrants from coastal river systems. Although records indicate that crocodiles are found over a wide area of the Far Northern Section of the Marine Park, they only occur at low density and no nesting in the World Heritage Area has been reported. Between 1977 and 1995 there were 84 sighting reports of crocodiles or their tracks. The primary habitat for crocodiles on eastern Cape York Peninsula occurs in coastal river systems, therefore, crocodiles are not considered further in this report. Details on marine turtles and sea snakes are provided below.

MARINE TURTLES

STATE

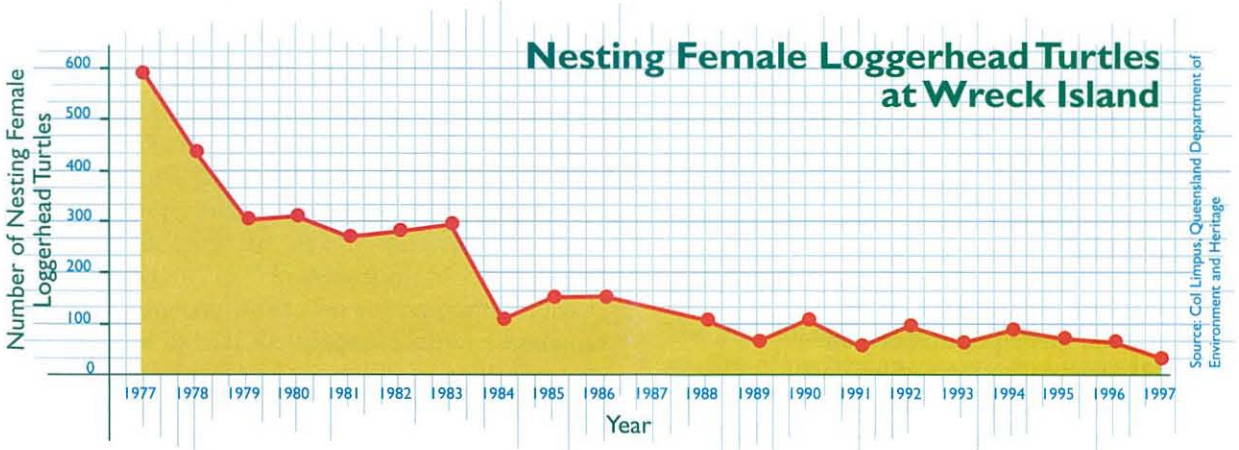
Of the world's seven species of marine turtles, six are found in the waters of the Great Barrier Reef. They are the green, hawksbill, loggerhead, flatback, olive Ridley and leatherback turtles. One of these, the flatback, nests only on Australian beaches. Out of the six species, four (green, loggerhead, hawksbill and flatback) have internationally significant populations in the World Heritage Area. The Great Barrier Reef is one of the few remaining havens for marine turtles in the world.

Marine turtles aggregate for breeding at a limited number of nesting beaches, with individual females always returning to nest at beaches in the same area where they were born. Examples from the World Heritage Area include Raine and Heron islands which are internationally significant green turtle nesting beaches, and Wreck Island, a major loggerhead nesting beach. Marine turtles can migrate as much as 2600 km between nesting beaches and feeding areas, but show great fidelity to both feeding and nesting sites.

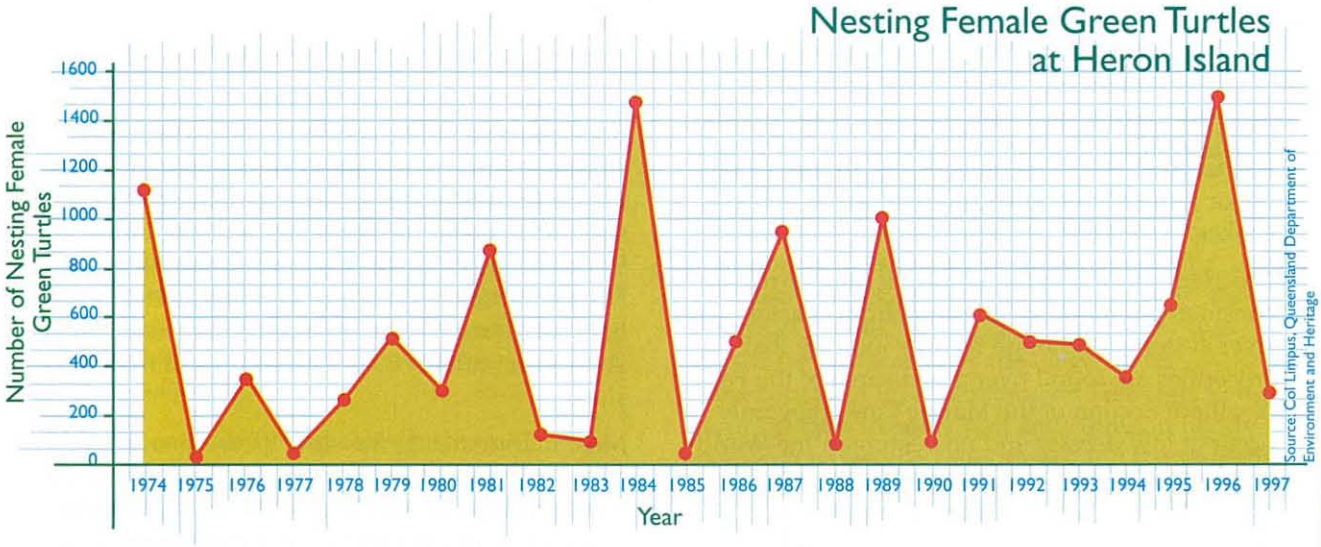
Most marine turtles are slow growing and take decades to reach sexual maturity. Females do not breed every year with periods between breeding episodes of five to eight years for green turtles and two to three years for flatback turtles having been measured. Marine turtles require high annual survivorship of adults and near-adults in order for populations to be maintained.

On a global scale, marine turtle populations are under threat. The hawksbill is listed as 'critically endangered' on the *1996 IUCN Red List of Threatened Animals*. This means that this species is at 'extremely high risk of extinction in the immediate future'. Green, olive Ridley, loggerhead and leatherback turtles are listed as 'endangered', meaning that they are at 'high risk of extinction in the near future'. Flatback turtles are listed as 'vulnerable', meaning that this species is at 'high risk of extinction in the medium-term future'.

In Australia, marine turtles are also in a vulnerable position. Apart from the flatback turtle, all species of marine turtles found in Australian waters are listed in the *Endangered Species Protection Act 1992*. The loggerhead turtle is listed as 'endangered' and the four other species as 'vulnerable'.



Each year during the nesting season, the number of nesting female loggerhead turtles on Wreck Island is counted during the last two weeks of December. Since 1977, numbers have fallen dramatically.



Numbers of nesting female green turtles at Heron Island have been extremely variable since 1974. This variability is caused by regional climatic cycles. While this variability makes it difficult to distinguish trends in the data, results from monitoring of green turtles in the northern Great Barrier Reef suggest that mortality of adults in distant feeding areas is unsustainable.

In the Great Barrier Reef World Heritage Area most scientific studies of turtle populations have concentrated on green and loggerhead turtles. The loggerhead is of particular concern. Since surveys began in the late 1970s the number of nesting females has steadily declined. The east Australian population of loggerhead turtles used to represent the bulk of the South Pacific stock (one of about eight loggerhead stocks globally). If this population disappears, it will represent the effective removal of the South Pacific stock. Because female turtles nest in the area where they hatched, it is highly unlikely that a stock that has died out would be recolonised by turtles from another stock somewhere else in the world.

Although the trends for green and hawksbill turtles are not as clear as those for loggerheads, there is evidence that populations of these species are also declining in the Great Barrier Reef World Heritage Area. There are no indications that flatback turtles are in decline.

Olive Ridley and leatherback turtles are uncommon in the Great Barrier Reef and have been the subject of little scientific research. The long-term trends in the populations of these species are unknown.

PRESSURE

Inside the Great Barrier Reef World Heritage Area, turtle populations are subjected to several sources of human impact. For some turtle species, the greatest pressures occur in overseas waters. Because turtles can regularly make migrations of up to thousands of kilometres, they can spend part of their time relatively well protected in Australian waters, but are exposed to significant pressures in overseas waters.

Although today turtles are protected from commercial exploitation in Australian waters, this has not always been the case. Commercial exploitation of turtles in eastern Australia was permitted until 1968.

Current human pressures on turtle populations in Australian waters include bycatch in trawl nets, traditional hunting, habitat degradation, bycatch in shark control programs, floating

TABLE 3 Conservation status of the six species of marine turtle found in the Great Barrier Reef

Species	Queensland Status *Nature Conservation Act 1992*	Australian Status *Endangered Species Protection Act 1992*
Green	Vulnerable	Vulnerable
Loggerhead	Endangered	Endangered
Hawksbill	Vulnerable	Vulnerable
Flatback	Vulnerable	Not listed
Leatherback	Endangered	Vulnerable
Olive Ridley	Endangered	Vulnerable

rubbish such as plastic and fishing line which can block guts after being eaten, and boat strike. Another human-related pressure is predation of turtle eggs and young by introduced species such as pigs and foxes.

Female turtles return to nest at beaches in the same area where they were born.

An estimated 1769 (+/- standard error of 960) turtles are caught in trawl nets in the Great Barrier Reef World Heritage Area each year. Between 29 and 138 of these captured turtles are estimated to drown. The most commonly caught species are flatback turtles and green turtles. Although loggerheads make up only 14% of the turtles caught, they are three times more likely to drown in a trawl net than flatback turtles. Most of the mortality that has led to the decline in the South Pacific population of loggerhead turtles occurs in Australian waters and is thought to be due to drowning in trawl nets.

The direct take of turtles in the Great Barrier Reef Marine Park is restricted to traditional hunting by indigenous communities living adjacent to the Marine Park. Turtle meat and eggs are an important traditional element of the diet of Australia's indigenous peoples, particularly for celebrations and family gatherings. However there are few statistics available for how many turtles are killed. One of the biggest problems with turtle hunting is that turtles targeted by hunters are mature females and, unfortunately, these are most critical to the reproductive success of the species.

Although turtles (almost entirely green turtles) are hunted in the Great Barrier Reef World Heritage Area, the numbers killed are small in comparison to those killed in neighbouring countries. Because turtles migrate over such large distances (up to 2600 km) hunting in neighbouring countries also affects populations in the Great Barrier Reef World Heritage Area. The combined hunting mortality in Australia and neighbouring countries is thought to exceed the capacity to replace losses. This is particularly true for green and hawksbill turtles.

A variety of human activities remove or degrade beach habitats which are nesting sites for turtles. Development may totally remove beach sand or restrict access to nesting areas, as has occurred along part of the beach at Heron Island. Lights from development (particularly street lights) can confuse new turtle hatchlings, causing them to move inland from their nest, instead of moving out to sea.

Between their introduction in the 1960s and about 1996, shark nets caught 2140 turtles in the World Heritage Area. Only 37% of these were released alive, the rest drowned.

RESPONSE

In Australia, marine turtles are protected under Commonwealth and State legislation. The Commonwealth is preparing a recovery plan for marine turtle species. A national Marine Turtle Recovery team consisting of representatives from relevant Commonwealth and State nature conservation and fishery agencies and other stakeholders has been convened. The team has developed a draft Recovery Plan for Marine Turtles in Australia, which identifies the objectives, criteria and actions for recovery of these turtle species.

The Plan identifies the loggerhead turtle as a species of particular concern and urges lead conservation and fisheries management agencies to reduce loggerhead mortality to almost zero.

Marine turtles can migrate long distances between their feeding and breeding grounds.

Authority and Great Barrier Reef Marine Park Authority have all identified the introduction of turtle excluder devices to minimise, if not eliminate, bycatch of turtles as an urgently required measure. The Queensland Fisheries Management Authority has proposed the target of reducing trawl-induced turtle deaths to negligible levels by 2000. Further details of management arrangements for the east coast trawl fishery can be found in *Management Status – Fisheries*.

All turtle species found in the Great Barrier Reef World Heritage Area are protected under Appendix I of the Convention on International Trade in Endangered Species. This means that international trade in turtle products (such as shells or items made from turtle shell) is heavily regulated and illegal without special permits.

Because of long migrations between feeding and breeding grounds, most turtles swim through the waters of more than one country during their lives. Consequently, conservation efforts for turtles must be coordinated at an international level if they are to be successful. An international agreement between Australia, Indonesia, New Caledonia, Papua New Guinea, Solomon Islands and Vanuatu addressing the conservation of marine turtles is needed urgently.

Almost all major turtle nesting areas in and around the Great Barrier Reef World Heritage Area are in protected areas.

Although some turtle hunting is allowed within the World Heritage Area, it can only be carried out by indigenous peoples with an appropriate permit. Even with a permit, hunting is not allowed in preservation zones of the Marine Park.

In recognition of the problem of turtles being caught as bycatch in trawl nets, the Queensland Department of Primary Industries and the Queensland Commercial Fishermen's Organisation have developed guidelines for the release of turtles taken by trawlers.

One of the major issues under consideration in the ongoing development of a new management plan for the east coast otter trawl fishery is bycatch of endangered species, particularly turtles. The Trawl Fishery Management Advisory Committee, Queensland Fisheries Management

Concern over bycatch of shark nets has led to some nets being replaced with baited hooks. Shark nets are now only deployed at ten locations in the World Heritage Area, near Cairns, Townsville and Mackay. Replacement of nets with hooks has not eliminated bycatch of turtles, with loggerhead turtles still being caught on drum lines in southern Queensland.

A major tool for management is ongoing monitoring of turtle populations to provide information that allows informed management decisions. Annual monitoring of green, loggerhead, flatback and hawksbill turtle nesting populations is carried out.

Until there is robust demographic data for marine turtle populations in the Great Barrier Reef World Heritage Area, the management approach is a precautionary one which focuses on managing human activities which may impact on turtle populations.

SEA SNAKES

STATE

Seventeen species of sea snakes have been reported from the Great Barrier Reef World Heritage Area. Some species are found mostly on and around coral reefs whereas others are found over sandy and muddy areas of seabed. Of the 31 species found in northern Australian waters, 48% are endemic to the area, but none are endemic to the Great Barrier Reef.

There have been few studies of sea snake populations in the Great Barrier Reef and the status of populations is unknown. Even in the Gulf of Carpentaria, where there have been estimates of numbers of sea snakes killed in trawl nets (see *Pressure*), the impact of this mortality on the populations is not known.

PRESSURE

The species of sea snakes found mostly on and around coral reefs are more or less free from human pressure. However, some illegal collection of olive sea snakes for the aquarium trade does occur. Other species roam over the seabed away from the reefs, and these species are at risk from being caught and killed by trawlers. No figures for the number of sea snakes killed in this way are available from the Great Barrier Reef. However, estimates from the Gulf of Carpentaria in 1991 indicate that between 30 000 and 67 000 sea snakes were killed as a result of commercial prawn trawling.

RESPONSE

Until February 1998, there were two licences for the processing and sale of 10 000 sea snakes killed in trawl nets on Queensland's east coast. These licences have now lapsed and will not be renewed by the Queensland Department of Primary Industries.

Very little is know about the status of sea snake populations.

As with turtles, the introduction of appropriate bycatch reduction devices on trawl nets should greatly reduce the human pressures on sea snake populations.

Currently, there are no management measures directed specifically at sea snake conservation. Given the total lack of information on sea snake populations in the World Heritage Area it is impossible to know whether such management measures are required or not. Given this lack of information and the potential for some species of sea snakes to be caught in trawl nets, the only course of action is to use the precautionary approach in the short term and instigate a research program to fill the information void to allow informed management decisions in the long term.

SUMMARY

Marine Turtles

The Great Barrier Reef World Heritage Area contains six of the world's seven species of marine turtles. One of these nests only on Australian beaches. All of the species are classified as either vulnerable or endangered. Of the species for which population trends are known, the loggerhead has exhibited significant declines since 1977 and the green and hawksbill show indications of decline. The status of the other species is unclear.

Within the Great Barrier Reef, catch in trawl nets and shark nets, as well as indigenous hunting are important pressures. Significant pressure from hunting also exists outside Australia during periods when adult turtles migrate to other areas. The combined local and overseas mortality is probably not sustainable. Management efforts have been focused on protection of nesting sites, the development of methods to reduce mortality in nets, and the continuation of status monitoring. There is an identified need to develop international agreements for marine turtle conservation.

Sea Snakes

The status of sea snakes is virtually unknown, although a known pressure is being caught in prawn trawl nets. In the absence of status and trend information, management requirements are uncertain.

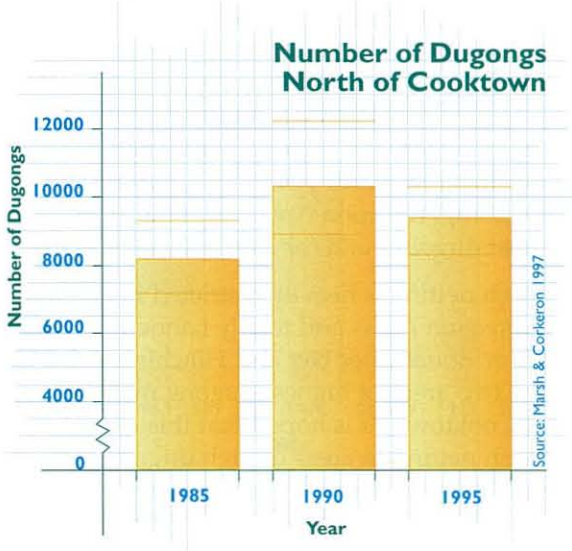
DUGONG

STATE

Dugongs (or sea cows) are marine mammals that are specialised for feeding on seagrasses. They have a very low reproductive rate. The maximum likely rate of increase of a dugong population is estimated at 5% per year, if all the females in the population are breeding at their maximum potential. Thus, in order for numbers to be maintained, adult survivorship must be higher than 95% each year. The maximum possible sustainable mortality rate of adult females killed by human activities is around 1 or 2%.

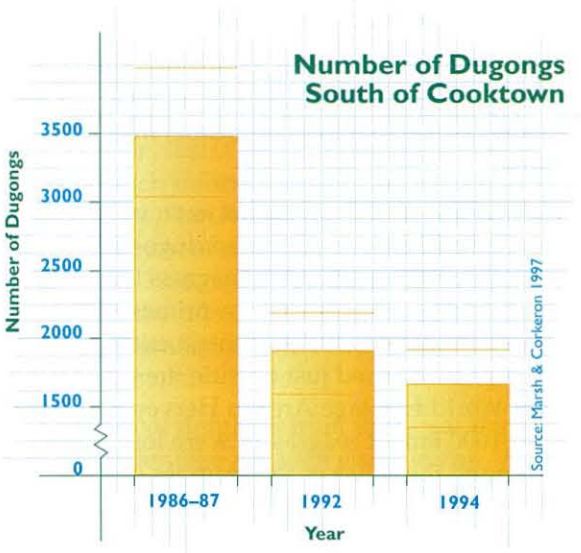
On a global scale, the dugong is listed as 'vulnerable' on the *1996 IUCN Red List of Threatened Animals*. This means that this species is at 'high risk of extinction in the medium-term future'. Under the Queensland *Nature Conservation Act 1992* the dugong is also listed as 'vulnerable'.

The waters of northern Australia, including the Great Barrier Reef World Heritage Area, contain a significant proportion of the world's dugong population with an estimated 15% of Australia's population being found in the World Heritage Area. Dedicated aerial surveys of dugong populations have been commissioned by the Great Barrier Reef Marine Park Authority and carried out by James Cook University since 1984.



The number of dugongs in the Great Barrier Reef World Heritage Area north of Cooktown has remained stable since surveys started in 1986. The lines above and below each bar show the standard error, an indication of the uncertainty associated with the measurement.

For the purposes of these dugong surveys, the World Heritage Area has been subdivided into two parts: north of Cooktown and south of Cooktown. North of Cooktown, surveys were carried out in 1984, 1985, 1990 and 1995. Over this time the dugong population was stable, with the minimum population estimate from 1995 being 8190 (+/- standard error of 1172) dugongs. However, surveys south of Cooktown in 1986–1987, 1992 and 1994 have documented a distinct decline in the dugong population. The 1994 population estimate is only about 48% of the 1986–87 estimate.



The number of dugongs in the Great Barrier Reef World Heritage Area south of Cooktown has fallen by about 50% since surveys started in 1986–87. The lines above and below each bar show the standard error, an indication of the uncertainty associated with the measurement.

PRESSURE

There are several sources of pressure on dugong populations from human activities. These include mesh nets, shark nets, traditional hunting, boat strike, and habitat loss and degradation.

Mesh netting is considered to be a significant cause of dugong mortality and some definite cases of dugongs being killed in mesh nets have been reported. However, no information on the actual numbers of dugongs killed in this way is available.

Another type of net responsible for dugong deaths is the shark net. Unlike mesh nets, the numbers of dugongs killed in shark nets have been fairly well documented. Since 1962, shark

nets have caught 654 dugongs, an average of about 18 per year. However, since the Shark Control Program was reviewed in 1992, the annual average has been 2.2. There have been no captures in the Great Barrier Reef World Heritage Area since 1995. On average, only 6.9% of dugongs caught in shark nets are definitely released alive.

Unlike dolphins and whales, dugongs feed mainly on plants.

Dugong meat is an important traditional element of the diet of Australia's indigenous peoples, particularly for celebrations and family gatherings. There are few statistics available on how many dugong are hunted, and most of what is available is out of date.

Boat strike is considered to be a potential source of dugong mortality. However, there is limited evidence of actual dugong deaths from this cause.

Habitat loss and degradation is an impact that can have disastrous effects on dugong populations. In particular, seagrass habitat is important as seagrasses are a primary food source for dugongs. The greatest example of such an impact occurred just outside the Great Barrier Reef World Heritage Area in Hervey Bay. More than 1000 km^2 of seagrasses were lost in 1992–93. Although the cause of the seagrass death was uncertain, it may have been caused by high turbidity water from flooding and run-off. Population estimates indicate that the number of dugongs in the area fell from 2200 in 1988 to 800 in 1994. It should be noted that seagrass die-off of this kind has not been documented from the World Heritage Area. Indeed, repeat seagrass surveys at the two localities with the highest dugong densities in the southern Great Barrier Reef, Hinchinbrook Island and Shoalwater Bay, have indicated that seagrass areas are stable at large scales. For more information on seagrass status and management activities, see *Environmental Status – Seagrasses*.

RESPONSE

The dugong in Australia is listed in Appendix II of the Convention on International Trade in Endangered Species, whereas the dugong in the rest of the world is listed in Appendix I. While the restrictions on trade for species in Appendix II are not as strong as those for species in Appendix I, this listing does recognise the vulnerable status of the dugong.

Although some dugong hunting is allowed within the World Heritage Area, it can only be carried out by indigenous peoples with an appropriate permit. Even with a permit, hunting is not allowed in Preservation Zones of the Marine Park. Within each community, permits to hunt dugong are allocated by Councils of Elders. Since becoming aware of the decline in dugong numbers south of Cooktown, Councils have voluntarily agreed not to harvest dugongs in this area. Further, the Great Barrier Reef Marine Park Authority has ceased to issue permits for dugong hunting south of Cooktown and there is currently no permitted dugong harvest in this area.

The most recent management action to protect dugong populations has been the introduction of Dugong Protection Areas, an initiative of the Great Barrier Reef Ministerial Council, the Great Barrier Reef Marine Park Authority and the Queensland Department of Environment and Heritage. In total, 16 Dugong Protection Areas have been declared, all south of Cooktown in the region where the dugong population has been declining in recent years. The areas chosen as Dugong Protection Areas were those with the most dugongs and/or extensive seagrass habitat.

Mesh netting is heavily restricted in Dugong Protection Areas and totally banned in two of them, Shoalwater Bay and Hinchinbrook Island, the two areas of highest dugong numbers south of Cooktown. It is hoped that this reduction in mesh netting in areas of high dugong numbers will assist the recovery of the dugong population south of Cooktown. More information on Dugong Protection Areas can be found in *Management Status – Threatened Species*.

Concern over catch of dugongs, as well as dolphins and turtles, in shark nets has led to

many nets being replaced with baited hooks. Shark nets are now only deployed at ten locations in the World Heritage Area, near Cairns, Townsville and Mackay.

Because of concern over dugong populations, extensive monitoring through aerial surveys and other research is continuing.

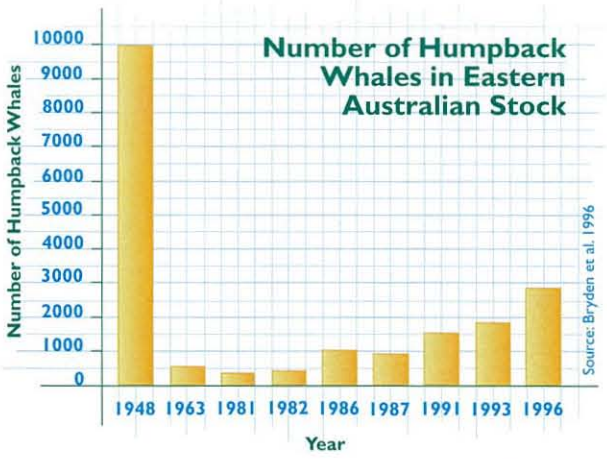
WHALES AND DOLPHINS

STATE

At least 26 species of whales and dolphins visit or are resident in the Great Barrier Reef World Heritage Area. Of these, two species of baleen whales, the humpback and the dwarf minke, are commonly seen during the winter.

There have been no dedicated studies of whale and dolphin populations in the World Heritage Area. However, since the early 1980s there have been annual surveys of humpback whales as they migrate north to the Great Barrier Reef at the start of winter. While these surveys do not take place inside the World Heritage Area, they are still counting the population of animals that inhabits the Area during winter. At this time of year, humpback whales are commonly seen in many parts of the World Heritage Area.

On a global scale, the humpback whale is listed as 'vulnerable' on the *1996 IUCN Red List of Threatened Animals*. This means that this species is at 'high risk of extinction in the medium term future'. The Commonwealth Government *Action Plan for Australian Cetaceans* also lists the humpback whale as 'vulnerable'.



During industrial whaling from 1949 to 1962, the estimated numbers of humpback whales in the eastern Australian stock fell from 10 000 to between 200 and 500. Since regular monitoring began in 1981, the population has shown a steady increase.

Large-scale, industrialised whaling between 1949 and 1962 (when the industry collapsed) seriously depleted the population of the eastern Australian humpback whale. Although there is debate about the accuracy of the figures, the only available estimates indicate that the population fell from 10 000 to 200–500 animals during the period of the whaling industry's activity. The most recent estimate of the size of this population is 3185 animals from a 1996 survey. Over the period 1981 to 1996, the estimated annual rate of increase of the population was 12.3%.

Two different forms, probably distinct species, of minke whale are found in Great Barrier Reef waters. The 'dark shoulder' minke apparently is restricted to the southern and central areas of the Great Barrier Reef, whereas the 'dwarf' minke is found throughout the area, with the largest number of records from the Cairns Section of the Marine Park. The 'dark shoulder' form migrates into Antarctic waters to feed and research there has led this form to be listed as 'secure' in the *Action Plan for Australian Cetaceans*. However, there is no such information for the 'dwarf' form and the Action Plan lists it as 'no category assigned because of insufficient information'. Similarly, the *1996 IUCN Red List of Threatened Animals* lists the minke whale as 'insufficiently known' (no distinction is made between the different forms).

Three species of dolphins from the Great Barrier Reef World Heritage Area are classified as inshore species: Indo-Pacific hump-backed dolphins, Irrawaddy dolphins and bottlenose dolphins. However, bottlenose dolphins are found throughout the World Heritage Area, not just inshore. Limited information on numbers of dolphins is available from observations made during dugong aerial surveys, however such surveys are often unable to identify what species, or even genus, of dolphin is seen. Thus counts may amalgamate as many as four genera. This lack of taxonomic resolution makes these counts of very limited use in assessing stocks of dolphins.

The difficulty of assessing dolphin populations is reflected in that both the *1996 IUCN Red List of Threatened Animals* and the *Action Plan for Australian Cetaceans* list most dolphins as 'insufficiently known'.

There is concern about apparent declines in populations of Indo-Pacific hump-backed dolphins and Irrawaddy dolphins throughout much of south-east Asia. Populations of these species around Australia may be the only ones that will survive into the next century. These

populations are thus considered to be the world's only remaining viable populations. However, there are two major problems with this contention. First, there is only very limited information on exactly how many of these animals are in Australian waters. Therefore, it is impossible to know for certain whether populations are increasing, remaining stable or decreasing. The only available information, on numbers of groups of humpback dolphins (not actual population estimates) sighted during aerial surveys, indicates that the population is probably declining. Second, there is strong evidence that Australian populations (at least of Irrawaddy dolphins) are genetically isolated from those in other parts of the world (e.g. south-east Asia), so the conservation of the Australian stock does not compensate for the loss of other populations.

Other whale and dolphin species reported from the Great Barrier Reef include spinner dolphins, pantropical spotted dolphins, false killer whales, killer whales, short-finned pilot whales, sperm whales and various beaked whales. Nothing is known of the status of these species in the Great Barrier Reef World Heritage Area, other than that they occur there. Some species, for example Longman's beaked whale, are known only from a single record.

PRESSURE

Whales and dolphins are subject to a wide variety of impacts from human activities, with different species being subject to different pressures. The most direct human effect on humpback and minke whales is the activity of whale watching. Drowning in mesh nets is an important potential pressure on inshore dolphins (for example Indo-Pacific hump-backed dolphins and Irrawaddy dolphins). Other impacts that are thought to affect whales and dolphins are prey depletion due to overfishing, pollution and habitat destruction from coastal development.

The annual migration of humpback whales along the east coast of Australia has led to the development of a tourist whale-watching industry, particularly in Hervey Bay. This industry is concentrated around the time when the whales are returning south and the females are with their recently born calves. Although Hervey Bay is just outside the World Heritage Area, the animals observed here will have come from the Great Barrier Reef, further north. Vessel activity from whale-watching operations has been shown to affect the behaviour of humpback whales. However, we do not yet know whether it has long-term effects such as changes in migration routes and habitat use or decreased reproductive success in the population. Until we are sure that whale watching does not have serious impacts on the whales, whale watching must be managed in a precautionary fashion to ensure that the whales are unharmed by human activities.

In addition to the whale-watching industry for humpbacks, there is a relatively new industry in watching dwarf minke whales. This industry is centred around the Ribbon Reefs, north of Port Douglas. The major difference between watching humpbacks and minkes is that all humpback watching occurs from on board a boat, whereas minke watching often occurs with the watchers in the water with the whales. This is such a new activity that the effects on the whales are not

Two different forms of minke whale are found on the Great Barrier Reef – 'dark shoulder' and 'dwarf'.

Bottlenose dolphins are found throughout the waters of the World Heritage Area.

fully documented yet. However, research into these effects has been carried out for the last three years.

As with dugongs, mesh netting is perceived to be a significant cause of mortality for inshore dolphin species and some definite cases of dolphin death in mesh nets have been reported. However, no information on actual numbers of dolphins killed in these nets has been collected.

Numbers of dolphins killed in shark nets have been recorded. Between their introduction in the 1960s and about 1996, shark nets caught 216 dolphins in the World Heritage Area. Only 10.2% of these were definitely released alive.

RESPONSE

At an international level, whales and dolphins receive protection from the International Whaling Commission, the Convention on the Conservation of Migratory Species of Wild Animals (The Bonn Convention) and the Convention on International Trade in Endangered Species of Wild Fauna and Flora, in all of which Australia plays an active role.

Nationally, the *Whale Protection Act 1980* is the main piece of legislation protecting whales and dolphins. It is effective throughout the Australian Exclusive Economic Zone. There are also controls under the Commonwealth *Endangered Species Protection Act 1992*.

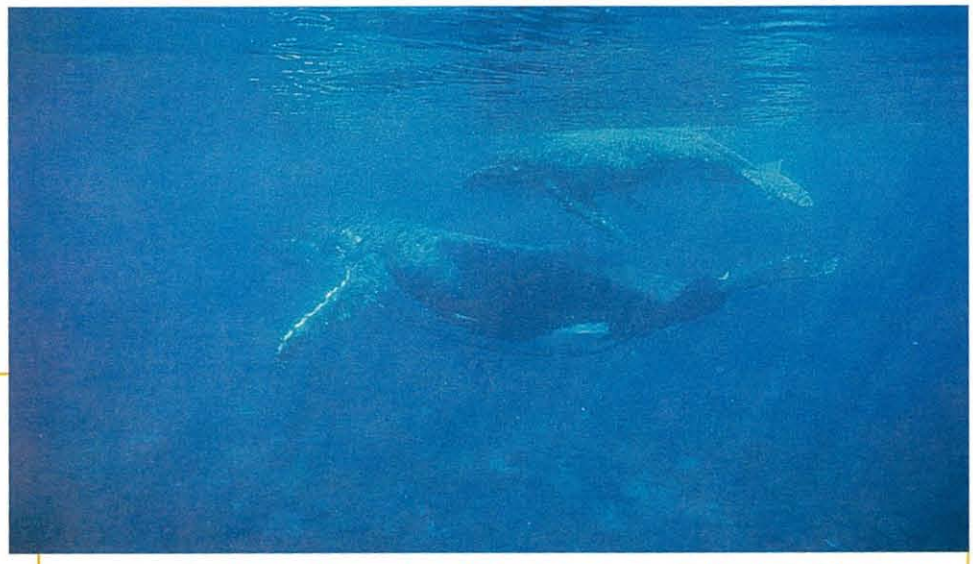
The Queensland Government Nature Conservation (Whales and Dolphins) Conservation Plan 1997 effectively bans swimming with whales and dolphins in State waters and also bans whale watching in the Whitsunday Islands region, where mothers with calves are seen particularly frequently. There has been an effort to restrict whale watching of humpback whales to Hervey Bay, so that cumulative impacts of potential whale-watching activities along the length of the Queensland coast are reduced.

The fledgling industry of minke whale watching in the northern Great Barrier Reef requires further research. Guidelines for in-water minke whale watching have been developed from the results of recent research into this activity. Further development and adoption of guidelines for human behaviour will minimise, if not eliminate, impacts on the whales.

The most direct threats to whales and dolphins in the Great Barrier Reef World Heritage Area are directed at those species about whose populations we know the least. These are the inshore dolphin species such as the Irrawaddy dolphin and the Indo-Pacific hump-backed dolphin which are killed as bycatch in shark nets and net-based fishing.

Concern over catch of dolphins, as well as dugongs and turtles, in shark nets has led to many nets being replaced with baited hooks. Shark nets are now only deployed at ten locations in the World Heritage Area, near Cairns, Townsville and Mackay.

Mesh-netting restrictions in Dugong Protection Areas may reduce mortality of inshore dolphins. Development of methods for targeted monitoring of populations of these species and research into effects of human pressures is under way. This research will provide better information on which to base future management decisions. Until this information is available management decisions must be made using the Precautionary Principle.



Humpback whales can be sighted in Great Barrier Reef waters each winter as they undertake their annual migration.

SUMMARY

Dugongs

Dugongs are unusual coastal-dwelling marine mammals unrelated to whales and dolphins. Globally they are considered to be vulnerable to extinction. In the Great Barrier Reef World Heritage Area, repeated monitoring indicates that populations in the far north are relatively stable, whilst those south of Cooktown have declined by approximately 50% since 1986–87.

The principal pressures on dugong populations are mortality in mesh and shark nets, traditional hunting and boat strikes. In recognition of the possible role of mesh netting as a major contributor to the decline in dugongs south of Cooktown, Dugong Protection Areas have been established which eliminate or restrict mesh netting in significant dugong habitats. The use of shark nets has also been significantly reduced. In addition, indigenous communities have voluntarily suspended dugong hunting south of Cooktown and there is currently no permitted dugong harvest in this area.

Whales and Dolphins

Baleen whales in the Great Barrier Reef World Heritage Area include the humpback and two forms of minke whale. The humpback is currently recovering from intensive whaling which ceased in 1962, while the status of the minke whale is uncertain for one form and probably 'secure' for the other. Within the World Heritage Area a potential pressure is from the whale-watching industry. This new industry is being managed to minimise any stress to the animals.

Several species of dolphins or toothed whales inhabit the World Heritage Area but their status is not known. There is particular concern for two inshore species, the Indo-Pacific hump-backed dolphin and the Irrawaddy dolphin, due to their vulnerability to pressures such as mesh netting, shark nets and habitat destruction. It is possible these species are in decline but more information on their status is urgently required.

Environmental Status

Inter-reefal and Lagoonal Benthos

STATE

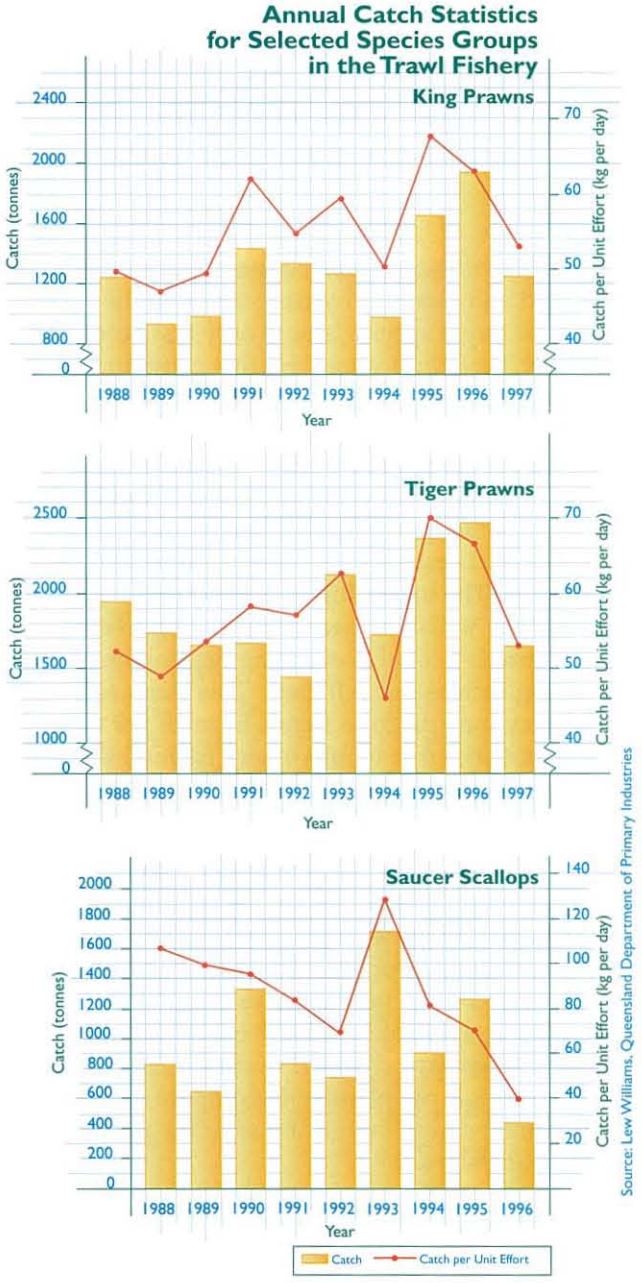
Only about 5% of the area of the Great Barrier Reef World Heritage Area is taken up by coral reefs. Islands also represent a small proportion, and most of the remaining 95% is seabed between reefs. This seabed is ecologically complex and comprises many different types of habitat but, generally, can be divided into the inter-reefal area and the lagoon. The lagoon is a relatively open area of primarily soft sediment seabed between the mainland and the part of the seabed where the reefs start. The inter-reef refers to the seabed found between coral reefs and is always further offshore than the lagoon. Generally speaking, in the northern part of the World Heritage Area the lagoon is much narrower (in some places almost non-existent) than in the southern part.

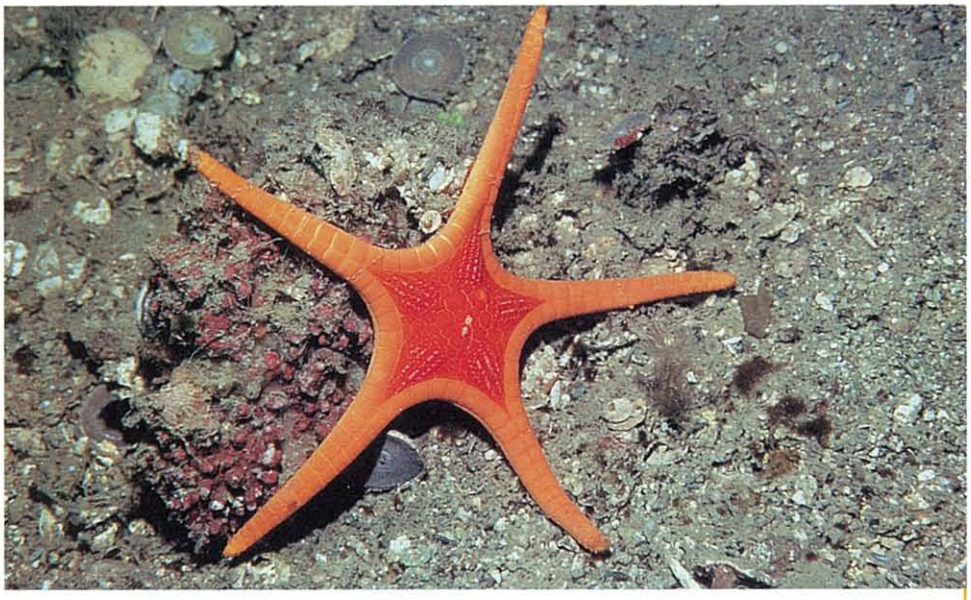
Close to shore, in the lagoon, sediments tend to be very fine (muddy) and mostly of land-based origin. Further offshore, in the inter-reef, sediments are coarser (sandy) and of sea-based origin. Interspersed throughout both the muddy and sandy areas are patches of hard substrate including rubble, bedrock, deep reef and shoal. Very different communities of plants and animals are associated with these different types of substrate. There is a clear cross-shelf zonation of lagoonal and inter-reefal benthic communities related to the change in seabed sediments. The muddier areas have lower numbers of animals and are less diverse than the sandier areas and the areas of hard substrate.

Despite their relatively vast geographical extent, lagoonal and inter-reefal seabed areas generally are much less studied and less visited than coral reefs. Despite this, what we do know about these areas of seabed indicates that they are critical elements of the Great Barrier Reef World Heritage Area ecosystem. In particular, the lagoonal and inter-reefal seabed is home to great biodiversity: thousands of species, many or most unnamed as yet.

In some ways, the lagoon and inter-reef overlap with some of the other categories considered in this report. For example, most seagrass habitat occurs within the lagoon and inter-reef (some of it is found on top of coral reefs). In this section, we will consider those elements of the lagoon and inter-reef not dealt with elsewhere.

The state of inter-reefal and lagoonal benthos can be viewed from two perspectives. Firstly, there is the fisheries perspective of the relationships between stock, catch and effort for the species of commercial interest living in these areas. Secondly, there is the ecosystem perspective of the state of the community of plants and animals as a whole.





This seastar is just one of the rich diversity of species found on the sand and mud in lagoonal and inter-reefal areas.

From the commercial species perspective, detailed and quantitative assessment of the status of target species is now only just becoming a reality. Early indications are that most major target species in the Queensland Trawl Fishery are being exploited at a high level. Catch levels of the major target species have been variable for the past eight to ten years and catch per unit effort of some species (particularly saucer scallops and eastern king prawns) have declined over time. The increasing use of modern technology in fishing gear and navigation aids (for example Global Positioning Systems) makes trawling increasingly efficient. This increase in efficiency may disguise trends in catch per unit effort statistics that would otherwise indicate decreasing stocks.

From the perspective of the whole ecosystem, it is very difficult to determine the state of the seabed communities. Despite the geographical extent and biological importance of these areas, only a small number of descriptive studies have been carried out. There is no history of scientific monitoring available to describe how the seabed communities have changed over time. In particular, it is not possible to compare seabed communities from before and after the practice of trawling started.

Despite the lack of this kind of monitoring, research into the effects of trawling has been conducted. The results are described in *Pressure*. From these results, it seems reasonable to conclude that trawling has significantly altered the seabed communities of some areas of the inter-reef and lagoon.

PRESSURE

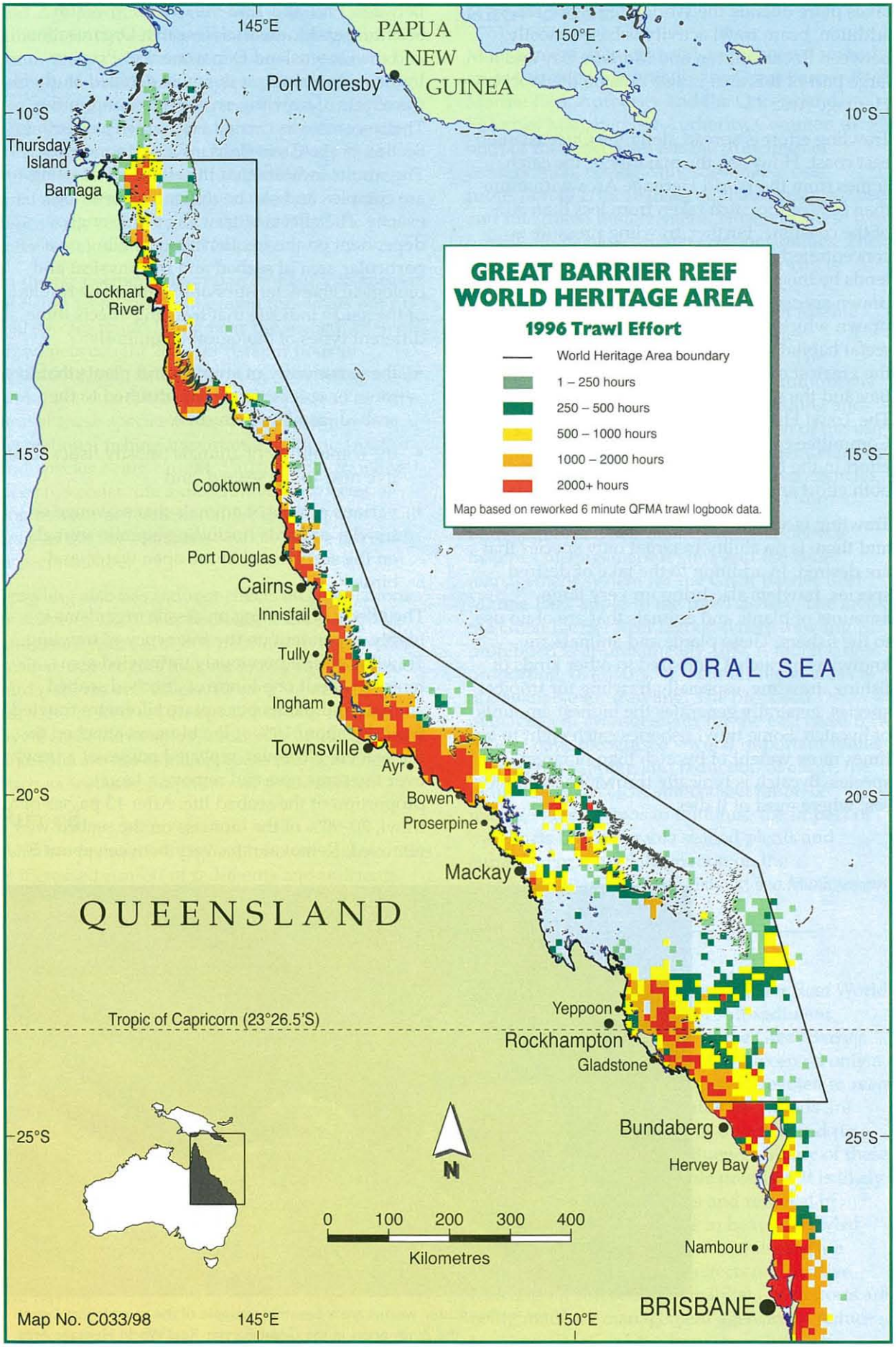
There are two obvious, identifiable sources of human pressure on the inter-reefal and lagoonal benthos: trawling and increased run-off from the land (including sediments, nutrients and pollutants). Relatively speaking, far more information exists about trawling and its effects on these seabed communities than about increased run-off.

Trawling

The trawling industry in Queensland produces up to 10 000 tonnes of product with a value of approximately $150 000 000 per year and employs around 8000 people. Most of the Queensland catch is taken from the Great Barrier Reef World Heritage Area. Target species groups are prawns, scallops and bugs. In addition, sand crabs, squid and a few fish species are also caught. Only seven of the 22 species of penaeid prawns found in the World Heritage Area are of commercial significance.

In order to take part in this trawl fishery, a boat must have a licence from the Queensland Fisheries Management Authority. There are currently about 840 boats licensed to fish for prawns and scallops with otter trawl gear. On average, each trawler fishes 100 days or nights per year. Thus, there is latent effort in the fishery: trawlers could considerably increase their effort levels if economic reasons to do so developed.

A further 210 boats are licensed to fish for prawns in inshore and estuarine waters with beam trawl gear. The fishing in estuarine areas


GREAT BARRIER REEF
WORLD HERITAGE AREA
1996 Trawl Effort
World Heritage Area boundary
1 – 250 hours
250 – 500 hours
500 – 1000 hours
1000 – 2000 hours
2000+ hours
Map based on reworked 6 minute QFMA trawl logbook data.
PAPUA NEW GUINEA
Port Moresby
Thursday Island
Bamaga
Lockhart River
Cooktown
Port Douglas
Cairns
Innisfail
Tully
Ingham
Townsville
Ayr
Bowen
Proserpine
Mackay
Yeppoon
Rockhampton
Gladstone
Bundaberg
Hervey Bay
Nambour
BRISBANE
CORAL SEA
QUEENSLAND
Tropic of Capricorn (23°26.5'S)
145°E
150°E
10°S
15°S
20°S
25°S
N
0 100 200 300 400
Kilometres
Map No. C033/98

takes place outside the World Heritage Area. In addition, beam trawl activity is based mostly between Rockhampton and Moreton Bay and a large part of this area is also outside the World Heritage Area.

Trawling effort is spread along the Queensland east coast. However, the majority of the catch comes from the World Heritage Area with more than 50% of the catch taken from less than 30% of the coastline. Further, trawling pressure is concentrated in the lagoonal area because it tends be the preferred habitat for commercial prawn species, other than the red spot king prawn which is associated with reefal and inter-reefal habitats. Within the World Heritage Area the greatest catch comes from Princess Charlotte Bay and the waters offshore from Townsville. The Trawl Fishery Management Advisory Committee considers that there is too much effort in the fishery and there is a need to reduce both effort and the number of vessels.

Trawling is a very unselective method of fishing and there is no ability to target only species that are desired. In addition to the take of desired species, trawlers also bring up very large amounts of plants and animals that are of no use to the fishers. These plants and animals are known as bycatch. Compared to other kinds of fishing, trawling, especially trawling for tropical species, generally generates the highest amounts of bycatch. Some trawl fisheries catch eight to ten times more weight of bycatch than of target species. Bycatch is typically thrown back into the sea, where most of it dies.

Between 1991 and 1996 the Commonwealth Scientific and Industrial Research Organisation and the Queensland Department of Primary Industries carried out the most detailed study of the effects of trawling on seabed communities. The research was carried out in the Far Northern Section of the Great Barrier Reef Marine Park. The results indicate that the effects of trawling are complex and can be difficult to describe exactly. The effects of trawling are strongly dependent on the frequency of trawling on a particular area of seabed and the physical and biological characteristics of the area. The results of the study indicate that trawling affects three different types of biological community:

- the community of animals and plants that live more or less permanently attached to the seabed (sessile organisms),
- the community of animals (mostly fishes) that live near to the seabed, and
- various groups of animals that scavenge on trawler discards (including aquatic animals on the seabed and in the open water, and birds).

The effects of trawling on sessile organisms is highly dependent on the frequency of trawling. Trawling over a previously untrawled area removes about one tonne of attached seabed animals and plants per square kilometre trawled, typically about 10% of the biomass attached to the seabed. However, repeated passes of a trawl over the same area can remove a large proportion of the seabed life. After 13 passes of a trawl, 70–90% of the biomass on the seabed was removed. Removal rates vary between about 5%

These feather-duster worms are a beautiful example of the animals that live on the sandy areas in the Great Barrier Reef World Heritage Area.

and 20% per trawl for different species. These differences between species cause changes in community composition of intensively trawled seabed. In practice, the typical pattern of commercial trawling is to trawl many times over high-yielding areas. Thus, areas subject to such intensive commercial trawling are likely to be subjected to significant impacts. However, the total area of seabed that is trawled 13 or more times each year may be less than 1% of the total inter-reefal and lagoonal habitat.

In the far northern Great Barrier Reef, 245 species of fishes were caught in prawn trawl nets out of 340 species found living near the seabed. Prawn trawl nets caught 28 kg of fish per hour of operation, with fish comprising between one-half and three-quarters of the bycatch. However, very few of these species were of commercial or recreational fishing importance, with no trout or cod species being caught. Thus, prawn trawling does not constitute a direct threat to species of commercial or recreational fishing importance, at least in the Far Northern Section where the study was conducted.

Trawling also has indirect effects on populations of scavengers such as seabirds, sharks, dolphins and small fishes and invertebrates living on the seabed. Scavengers that are highly mobile (mostly birds, sharks and dolphins) congregate around trawlers to feed on the bycatch as it is thrown overboard. Between 60% and 90% of discards sink and thus are not available to surface scavengers such as seabirds, dolphins and some sharks.

Run-off

Another pressure on lagoonal seabed communities is increased run-off of sediments and nutrients from the land. This increased run-off is a result of human development, particularly agriculture, on the mainland adjacent to the World Heritage Area. For more information on the processes involved, see *Environmental Status – Water Quality*. It is possible that increased run-off, particularly of sediments, could adversely affect nearshore seabed communities. One mechanism by which this could happen is through fine sediment smothering animals. However, such impacts would be restricted to within a few kilometres of the coast. Further, no research has been specifically directed to answering the question of whether or not nearshore seabed communities have been affected by these pressures. Thus, while such pressures are a concern, we do not have information about how much, if any, effect they are having.

RESPONSE

Management of inter-reefal and lagoonal seabed areas is carried out both by the Great Barrier Reef Marine Park Authority and the Queensland Fisheries Management Authority. Common to both of these agencies are the principles of conservation, ecologically sustainable use, protection of critical areas, equitable resource use and integrated management. However, these two organisations have separate responsibilities. The Great Barrier Reef Marine Park Authority is primarily responsible for the care and development of the Great Barrier Reef Marine Park and is not responsible for fisheries management, except for this purpose. The Queensland Fisheries Management Authority is responsible for the management of fishing and collecting operations and optimisation of the use of available fisheries resources. Further details of the management activities of these two agencies can be found in *Management Status – Fisheries*.

Both spatial and seasonal closures under the fisheries management regime and the zonal management system for the Great Barrier Reef Marine Park apply to the trawl fishery. The area of the Great Barrier Reef lagoon where trawling is prohibited is approximately 10%. A much larger proportion, over 50%, of the inter-reefal areas is not available for trawling. The proposed management arrangements for the east coast trawl fishery have recognised several important issues such as the capping and reduction of effort, the reduction of bycatch, and consideration of management options to minimise the impact of trawl nets on vulnerable seabed plants and animals. For more information on the management of the trawl fishery, see *Management Status – Fisheries*.

SUMMARY

The vast majority of the Great Barrier Reef World Heritage Area is made up of soft-sediment habitats between reefs and in the Great Barrier Reef lagoon. These habitats have received only a fraction of the scientific attention devoted to reefs and as a result both the status and trends are poorly known. As a result of trawling and (to a lesser extent) terrestrial influences, many of these areas are under considerable pressure. It is likely that the damage to habitats and removal of bycatch are not sustainable in heavily trawled areas. Ongoing research and monitoring are beginning to establish the effects of intensive trawling on soft sediment habitats and efforts are being made by management agencies to reduce trawling effort and the impacts on bycatch.

Management Status

Photo: Mark Johnson

Marine Park Management

Fisheries

Tourism

Threatened Species

Indigenous Issues

Water Quality and Coastal Development

Shipping and Oil Spills

Monitoring

The Great Barrier Reef Marine Park Authority is the lead agency for Great Barrier Reef World Heritage Area issues. It was established under the *Great Barrier Reef Marine Park Act 1975* as a Commonwealth statutory body. The Authority is the principal adviser to the Commonwealth Government on the care and development of the Great Barrier Reef Marine Park.

MANAGEMENT PHILOSOPHY

Four elements underlie the management philosophy of the Great Barrier Reef Marine Park Authority:

- management at the ecosystem level to achieve overall protection of the ecosystem,
- conservation and reasonable use so that whilst the ecosystem is protected it also provides opportunities for sustainable use and enjoyment of the resources of the Great Barrier Reef,
- public participation or community involvement in the development and implementation of management, and
- monitoring and performance evaluation of management.

Management at the Ecosystem Level

Marine ecosystems are large; the plants and animals which settle on or pass by a coral reef or area of seabed may have been spawned by parents tens or hundreds of kilometres away. In turn, their offspring may migrate actively or be carried passively similar distances by tides and currents.

Water may carry food, nutrients, larvae or pollutants as well as being the home environment for many species which drift or swim throughout their lifecycle. Whatever is done to manage part of a marine ecosystem must take into account the influences carried by the water column.

The Great Barrier Reef Marine Park Act was among the first in the world to deal comprehensively with the management of a marine ecosystem. The values which led to the passage of the Act were also recognised in 1981 by the inscription of the Great Barrier Reef on the World Heritage List. The Great Barrier Reef Marine Park Act provides the framework for managing the Great Barrier Reef as a large ecosystem.

The Great Barrier Reef Region includes all of the Great Barrier Reef ecosystem, with the exception of the extreme north in Torres Strait. The Great Barrier Reef Marine Park, as declared, has five sections constituting approximately 98.5% of the Great Barrier Reef Region. Nevertheless, at the ecosystem level, the linkages between land and sea and the migration or transport of animals and plants in the water mass can mean that the constitutional boundaries related to low water have little relevance to the ecological communities of the Great Barrier Reef, the islands and adjacent coast.

In developing zoning plans to provide the strategic underpinning for management of the Great Barrier Reef, the Great Barrier Reef Marine Park Authority has placed a major emphasis on understanding the linkages between sites and activities within the Great Barrier Reef and between the adjacent mainland and the Great Barrier Reef.

Conservation and Reasonable Use

Meeting the conservation requirements of a large and interlinked ecosystem requires a comprehensive approach to management of human use and impacts. This cannot be achieved by focusing solely on some small subsamples which are allocated to restrictive entry conditions as strict nature reserves or national parks. The management of used areas in a way that buffers the more strictly protected areas is an important part of a comprehensive management approach of the whole context of use and impact.

The Great Barrier Reef Marine Park Act provides for conservation of the Great Barrier Reef and reasonable use of the Great Barrier Reef Region. In doing this it anticipated the global movement towards ecologically sustainable development.

Four of the five Marine Park sections are covered by zoning plans which provide the strategic framework for management. Each zoning plan provides for protection and sustainable use of the natural ecosystem and thus meets the criteria of a Category 6 'Protected Area' under the IUCN (World Conservation Union) *Guidelines for Protected Area Management Categories*.

Within the zoning plans there are strictly protected areas which meet the criteria of IUCN Category 1 'Preservation or Scientific Research Zones'. There are also national park zones

equivalent to IUCN Category 2. Other zones, including habitat protection, general use and buffer zones provide for a range of conservation measures consistent with sustainable use and addressing the rest of the spectrum of the IUCN Protected Area categories.

The Category 1 and Category 2 Protected Areas address the objective of providing for representative strictly protected areas covering each of the habitat types of the Great Barrier Reef Region. In these categories coral reefs are well represented but the Authority is working to ensure significant representation of all habitat types of the Great Barrier Reef Region.

The distribution of the highly protected Category 1 and 2 zones has been developed with a view to providing the best possible network having regard to water current flows so that the protected areas can serve as sources of recruits to other areas of the Reef which may be used for a range of activities, including fishing and tourism.

While the zoning plans provide largely for spatial separation into zones, seasonal closure and other temporary closure measures provide for temporal separation of activities, particularly where such separation or closure protects animals or plants at sensitive times of their reproductive cycle. In addition to the spatial and temporal management, the zoning plans establish a system for permitting activities which need to be considered on a case-by-case basis to address individual or cumulative impacts.

The strategic framework of the zoning plans is augmented at the tactical level by site and area management plans for particularly sensitive or heavily used areas. Management plans must be consistent with the zoning for the area in question but they address issues such as recreational and tourist setting, the protection of fragile areas and the placement and management of moorings. They also establish policy in relation to permitting activities.

The broader context of management is addressed by long-range, 25-year strategic planning. In 1993–94, a total of 67 community and interest groups took part in a process which identified long-term goals and established objectives for the various group and agencies involved in management of the Great Barrier Reef World Heritage Area.

Public Participation or Community Involvement

At the socioeconomic level, most use of the Reef, many impacts upon the Reef and much of the concern about the future of the Reef come from the mainland or islands which are part of Queensland. The management of use and impacts and the achievement of reasonable, sustainable use must involve the people whose use and activities relate to the Reef. There are thus extensive formal and informal means for achieving community input and involvement in the work of the Great Barrier Reef Marine Park Authority.

The Great Barrier Reef Marine Park Act provides for Commonwealth, Queensland and community members of the Authority, which is the governing board for the Marine Park. It also provides for a Consultative Committee nominated half by the Commonwealth and half by Queensland. The Act provides in some detail for public participation in the development of

These volunteers from the Whitsundays dive industry are helping Marine Parks staff to lay out 'no anchoring' buoys.

zoning plans and, from the start, the Authority adopted a practice of public participation which has gone well beyond the basic requirements of the legislation.

In providing for reasonable and multiple use, the Great Barrier Reef Marine Park Act and the provision for the operation of the Authority reflect that management of the Great Barrier Reef has to be achieved through a partnership of the Commonwealth Government, the Queensland State Government and coastal communities of Queensland.

Although the national and global significance of the Great Barrier Reef is well recognised, management is planned and conducted in the context that the coastal communities of Queensland and the governments which represent them are essential participants in any effective management of the Great Barrier Reef ecosystem.

Monitoring and Performance Evaluation of Management

The Authority and its partner agencies operate by establishing and implementing a management regime for the Great Barrier Reef Marine Park and World Heritage Area. This engenders a responsibility to monitor the condition of the managed system and the effectiveness of implementation of the management. The biophysical condition of the Great Barrier Reef Region is addressed by this State of the Great Barrier Reef World Heritage Report. The effectiveness of management is addressed through assessment and reporting of Authority programs and the day-to-day management of the Marine Park.

PERMITS

The Great Barrier Reef Marine Park zoning plans indicate which activities may or may not be carried out in an area and for which activities a Marine Parks permit is required. Permits specify the activities which are permitted, the locations where they may be conducted and any conditions which apply. The conditions are imposed to help ensure the protection of the values of the Marine Park and the amenity of other users. They vary depending on what you wish to do and where you wish to go. As a general guide, the following activities require a permit:

- most commercial activities including tourist operations,
- installation and operation of structures such as jetties, marinas, pontoons and mariculture facilities,
- any works, such as repairs to structures, dredging and dumping,
- placement and operation of moorings,
- anchoring or mooring for an extended period,
- waste discharge from a fixed structure,
- research,
- educational programs, and
- traditional hunting.

Permits are jointly assessed by the Great Barrier Reef Marine Park Authority and the Queensland Department of Environment and Heritage. There is a comprehensive list of criteria by which each permit application is assessed. If the proposal is likely to affect the environment to a significant extent, the Authority considers whether there are any prudent and feasible alternatives. If there are none, then the application is designated under the Commonwealth *Environment Protection (Impact of Proposals) Act 1974* and an Environmental Impact Statement may be required before a decision is made on the permit application.

RESOURCES

The Great Barrier Reef Marine Park Authority works jointly with a range of Commonwealth and Queensland Government agencies to effectively achieve Marine Park management objectives. Management partners include the Queensland Department of Environment and Heritage and the Queensland Fisheries Management Authority. Field management of the Marine Park is implemented through day-to-day management programs which are carried out by Queensland Government agencies.

Launched in 1994, the 25 Year Strategic Plan for the Great Barrier Reef World Heritage Area provides guidance for the many agencies, organisations and individuals involved in the use and management of the World Heritage Area. In the Plan it was estimated that the level of government appropriation applied to the Great Barrier Reef World Heritage Area was $60–100 million per year across all agencies. It was intended that the Plan would be implemented within government appropriations and non-government organisations' budgets to the maximum practicable extent.

A significant proportion of the research needs identified in the 25 Year Strategic Plan were to be addressed by the Cooperative Research Centre

for Ecologically Sustainable Development of the Great Barrier Reef for which Commonwealth funding of $12.955 million was assured over seven years from July 1993. Special funding was to be sought for specific objectives under the Plan where appropriate. Other potential funding sources included special initiatives related to the Great Barrier Reef; cooperative arrangements between Governments and users on the application of user pays monies from Marine Parks and National Parks; research and development corporation programs; special Commonwealth funding programs (e.g. Ocean Rescue 2000); and a potential World Heritage Area Foundation.

Since 1993 a reduction in Government outlays has been replaced by increased reliance on user pays for the operation of commercial tourism activities within the Marine Park. The Environmental Management Charge is used to support the Authority's operations in managing the Marine Park and also partly funds the Authority's contribution to the Cooperative Research Centre for Ecologically Sustainable Development of the Great Barrier Reef.

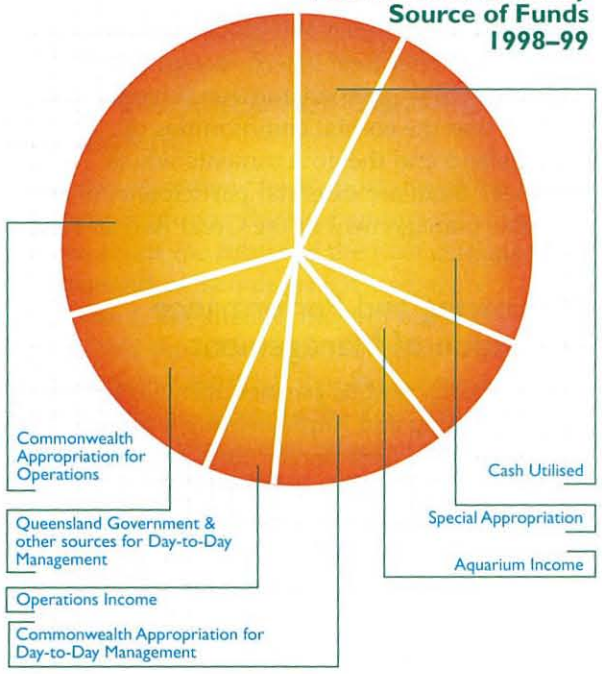
In 1998–99, the total funds available for management of the Great Barrier Reef Marine Park by the Authority will be $27.2 million.

Total funding to the Authority from Commonwealth Government outlays and the Environmental Management Charge will be $17.847 million. This total comprises funding for operations of $8.014 million, the Commonwealth contribution to day-to-day management of $3.983 million and $5.850 million from the Environmental Management Charge. The Queensland Government will contribute $3.983 million to match the Commonwealth contribution to day-to-day management. The 1998–99 revenue collected from tourism operators through the Environmental Management Charge is expected to increase by $2.850 million to $5.850 million following the Government's decision to increase the charge from $2 to $4 with effect from 1 April 1998. In addition, income is earned from the operation of the Great Barrier Reef Aquarium and the provision of training and advisory services.

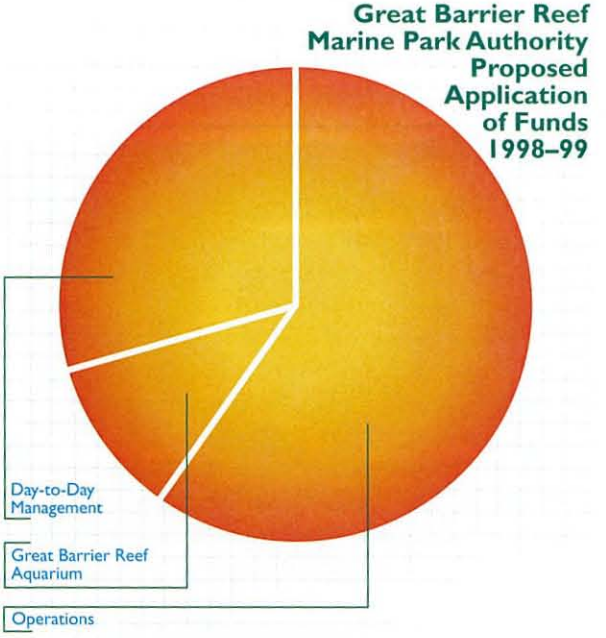
Expenditure is split between Authority operations, the Great Barrier Reef Aquarium and day-to-day management. Operational expenditure includes management of the critical issues, planning, environmental impact management, indigenous cultural liaison, information support, and corporate support.

The staff level for Authority operations is equivalent to 110 full-time staff. Approximately one hundred Queensland Department of Environment and Heritage staff are involved in the day-to-day management of the Marine Park. The staff level for the Great Barrier Reef Aquarium is equivalent to 27 full-time staff.

Great Barrier Reef Marine Park Authority Source of Funds 1998–99



Great Barrier Reef Marine Park Authority Proposed Application of Funds 1998–99



ENVIRONMENTAL MANAGEMENT CHARGE

In 1993 the Commonwealth Government introduced an operating charge, the Environmental Management Charge. The objective of the charge was to recover part of the increasing management, research and education costs associated with a marked increase in use of the Marine Park, particularly by tourism. The charge applies to all commercial operators who hold Marine Park permits.

A standard tourist operation charge, currently equivalent to $4 per visitor per day (with some concessions), applies to the majority of permitted tourist operations. These operations include day trips, extended charters, bareboats, cruise ships, guided snorkelling tours and some aircraft operations. Charges for non-standard operations reflect the size and nature of the operation, and apply to facilities like pontoons and marinas, and non-tourist related commercial operations like mariculture facilities. Increases in the Environmental Management Charge are now linked to the Consumer Price Index.

With the introduction of the Environmental Management Charge, all operators have been required to complete a logbook provided by the Authority. While the logbooks provide data on which the payments are based, they also provide useful information on tourism use for planning and other purposes.

MANAGEMENT FOCUS

In March 1998 the Commonwealth Minister for the Environment announced reforms to the administration of the Great Barrier Reef Marine Park Authority. These reforms will result in a more efficient and effective organisation. Implemented in July 1998 the new administrative structure is based upon four critical issue groups, each reflecting a key challenge in protecting and managing the Great Barrier Reef. The Authority will also rationalise its consultative processes so that it is more responsive to the needs of the community and key stakeholders including tourism operators, the fishing industry, and indigenous groups.

Conservation of the Great Barrier Reef will continue to be the Authority's primary obligation. The Authority's challenge is to ensure that valuable tourist and commercial fishing industries worth around $1.3 billion per annum and other important uses such as adjacent land use, shipping and recreational boating continue to operate on an ecologically sustainable basis.

The Authority's work program focuses around management of four critical issues and its activities over the next five years will be guided by a work program currently in preparation. The four critical issues for appropriate protection and management of use of the Great Barrier Reef Marine Park and World Heritage Area are:

- **Conservation, Biodiversity and World Heritage** – Protection of the natural values of the World Heritage Area and meeting the obligations of the World Heritage Area Convention will be achieved by protecting threatened species, the provision of a system of protected representative areas and improving the understanding of the effects of large-scale disturbances such as the crown-of-thorns starfish.
- **Tourism and Recreation** – Tourism is the main commercial use of the Marine Park. It contributes over $1 billion to the Australian economy per annum and brings 1.6 million visitors to the Great Barrier Reef. Park management aims at reducing the risk of adverse tourism impacts while providing diverse tourist opportunities.
- **Fisheries** – The maintenance of ecologically sustainable fisheries will be achieved in collaboration with Queensland fisheries management agencies. The Authority is working to obtain a better understanding of fishing activities and their impact on the Great Barrier Reef through a number of strategies including a comprehensive research program into the effects of fishing, monitoring fishing catch and effort, identifying major or critical habitats and actively supporting technology to reduce fishing bycatch.
- **Water Quality and Coastal Development** – The risk of degradation of the Great Barrier Reef through water pollution, impacts of coastal development and land use must be minimised. The Authority is working with Queensland and local governments on management arrangements to reduce sediment, nutrient and other land-based run-off that impacts on the health of adjacent marine areas. Long-term monitoring programs are being conducted to determine the state of water quality throughout the Reef and assess threats from pollution. The Authority is working with the Australian Maritime Safety Authority on improving oil spill contingency planning and response, navigational aids and ship reporting systems.

OVERVIEW

Fishing, the largest harvesting activity in the World Heritage Area, includes the major commercial fisheries of prawn trawling, reef line fishing and inshore fish netting and crabbing, in addition to minor fisheries for aquarium fishes, coral, bêche-de-mer, and trochus shell. The direct economic value of the commercial fishery in the Great Barrier Reef Region in 1996 was estimated at $143 000 000. Recreational fishing is an important activity with an estimated 24 300 privately registered boats annually fishing in the Great Barrier Reef Region. Traditional fisheries also occur adjacent to indigenous communities.

Under the offshore constitutional settlement between the Australian States and the Australian Government the management of fisheries within the Great Barrier Reef Marine Park is the responsibility of the Queensland Government through the Queensland Fisheries Management Authority and the Queensland Department of Primary Industries. The Great Barrier Reef Marine Park Authority, within its aim to protect the natural qualities of the Great Barrier Reef whilst providing for reasonable use of the Reef region, exercises control over fishing by virtue of the use of management zones which restrict certain fishing activities in specific areas. The Great Barrier Reef Marine Park Authority well recognises that the harvesting of fishes, prawns and other living resources is an established reasonable use of the Marine Park, but acknowledges that fishing affects target species, non-target species and their habitats and hence has the potential for producing ecological effects in both the fished areas and the reef system as a whole.

Because of the potential overlap between the activities of the Great Barrier Reef Marine Park Authority and fisheries management agencies, a memorandum of understanding was established between the agencies to clarify roles and responsibilities. As outlined in this memorandum, the responsibilities of the Great Barrier Reef Marine Park Authority are primarily the care and development of the Marine Park and not specifically for fisheries management. Primarily, the fisheries agencies' responsibilities are defined as the management of fishing and collecting operations and optimisation of the use of available fisheries resources.

Common to the charter of all resource management agencies are the principles of conservation, ecologically sustainable use, the protection of critical areas, equitable resource use and an integrated management approach which involves the preparation of management plans in consultation with the major users and interest groups. These principles are applied as effectively as possible but, for most of the fisheries within the Great Barrier Reef, the issues are extremely complex. Such issues include, in some cases, declining regional catches; decreased average size of fishes; increased fishing effort; excess capacity in the fishery; potential impacts of fishing activities on incidentally caught species, some of which are endangered; the impacts of fishing on the marine habitat; the increased significance of the recreational fishery in resource allocation; indigenous use and rights to the resource, and issues associated with compliance of fisheries and marine park management regulations.

MANAGEMENT ARRANGEMENTS

Queensland Fisheries Management Authority

The *Fisheries Act 1994* and the *Fisheries Regulation 1995* detail the legislative arrangements that apply to fisheries in Queensland. The Act describes the arrangements for developing, implementing and repealing fisheries management plans. Management plans can be applied to specific fisheries and can be much more flexible and prescriptive than fisheries regulations. In general for commercial fisheries, controls on effort and catch are achieved through limited entry, gear type and size restrictions, species size restrictions, and area and seasonal closures. Recreational fisheries are managed primarily by gear type and size restrictions, species size restrictions, area and seasonal closures, and bag limits on most popular species.

The Queensland Fisheries Management Authority has established a system of Management Advisory Committees for all the major fisheries in Queensland. The Management Advisory Committees are expertise-based and contain representation from all major stakeholder groups including recreational and commercial fishing, marine park managers, enforcement officers, research scientists, conservation groups

and Aboriginal and Torres Strait Islander peoples. The Management Advisory Committee system works well in ensuring all interests are considered in the management of a fishery.

On a more regional scale the Queensland Fisheries Management Authority has developed Zonal Advisory Committees which consider local fisheries-related matters. The Zonal Advisory Committees have representation from local commercial and recreational fishing interests; conservation, local council and local Aboriginal and Torres Strait Islander interests; and local representatives of relevant State government agencies. The Management Advisory Committees and Zonal Advisory Committees meet on a quarterly basis and report directly to the Queensland Fisheries Management Authority Board. Currently, the Management Advisory Committees are undertaking a review of the management of all major fisheries in Queensland.

Great Barrier Reef Marine Park Authority

The *Great Barrier Reef Marine Park Act 1975* provides for the establishment, control, care and development of the Great Barrier Reef Marine Park. This Act has significant influence on the management and accessing of fish stocks principally via the Great Barrier Reef Marine Park Authority's zoning plans that regulate activities including fishing. Areas of the Great Barrier Reef Marine Park are zoned in accordance with a number of objectives including the conservation of the Great Barrier Reef and the regulation of use so as to protect the Great Barrier Reef while allowing for reasonable use. The Great Barrier Reef Marine Park Authority is also required to have regard to the maintenance of the outstanding natural values of the Great Barrier Reef World Heritage Area.

The Great Barrier Reef Marine Park Authority thus has significant responsibilities for ensuring the conservation of fish stocks, and the environment that sustains them. This range of responsibilities creates the requirement for fishing in the Great Barrier Reef Marine Park to be conducted according to management practices that are assuredly ecologically sustainable.

The zoning plans for each section of the Marine Park were to have been reviewed every five years. In recent years this period has been more protracted due to the greater activity in many areas of the Marine Park leading to a greater complexity in rezoning procedures. There is now a tendency to change from section-by-section reviews to Reef-wide amendments to zoning plans based on a particular theme or issue. It is hoped that such an approach will lead to greater consistency in zoning arrangements than exists currently among the different sections of the Marine Park.

The Queensland Fisheries Management Authority and the Great Barrier Reef Marine Park Authority consult regularly to ensure that fisheries and Marine Park management planning arrangements are complementary and compatible. The Great Barrier Reef Marine Park Authority also maintains its practice of consulting representatives of the commercial and recreational fishing organisations and individuals in the development and review of zoning plans. In practice, there is some overlap, but a good working arrangement has been established, with close involvement of the fisheries agencies when zoning plans are being developed and involvement of Great Barrier Reef Marine Park Authority staff in the Queensland Fisheries Management Authority management planning process.

CURRENT STATUS

The degree to which the fisheries and Marine Park management schemes protect fished and non-fished species and their habitats is difficult to assess but can be evaluated in relation to four of the major fisheries:

- trawl fishery
- reef fish line fishery
- inshore mesh net fishery
- harvest fisheries.

Trawl Fishery

The trawling effort for the east coast trawl fishery is spread along the Queensland coast, however most of the catch comes from the Great Barrier Reef World Heritage Area. The trawl fishery in the World Heritage Area occurs predominantly within the Great Barrier Reef lagoon, the area between the Queensland coastline and the western margin of the mid-shelf reef complex. Within the World Heritage Area the greatest catch comes from Princess Charlotte Bay and the waters offshore from Townsville.

The fishery has an inshore and an offshore component. Inshore are tiger prawn and banana prawn fisheries which occur to a depth of 40 m. The offshore fisheries target king prawns in the central and northern sections of the Marine Park (30–50 m depth) and scallops in the southern sections of the Marine Park. In addition, endeavour prawns and Moreton Bay bugs make up valuable bycatch in some areas.

The trawl fishery is a limited entry fishery. Licensed operators are free to fish anywhere within the World Heritage Area where trawl fishing is permitted. Restrictions are placed on the size and number of nets used and also their mesh size.

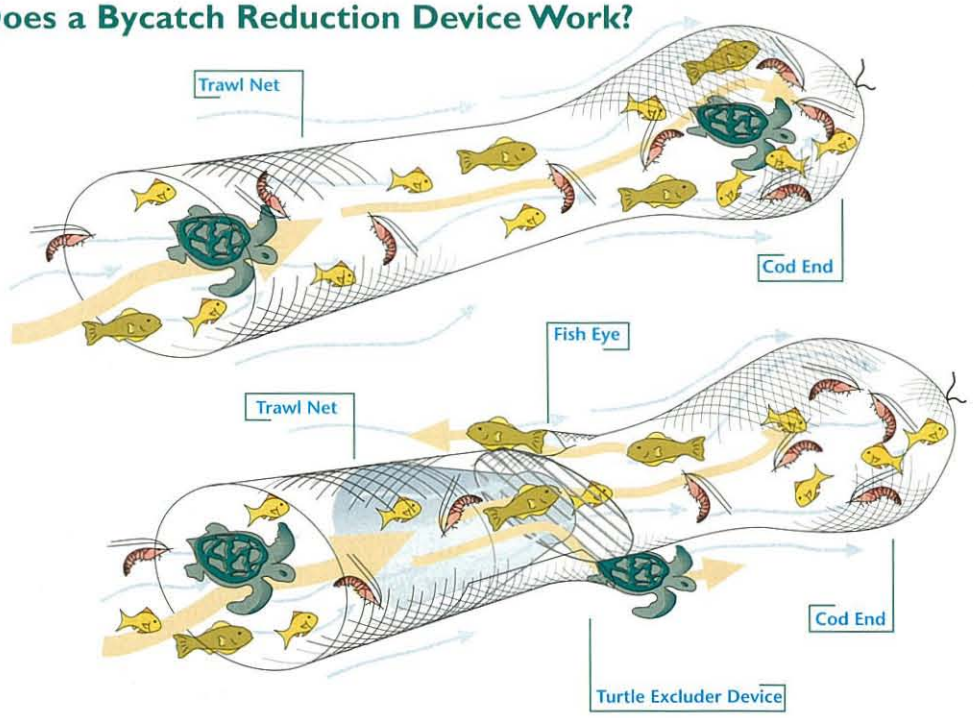
There are currently about 840 boats licensed to fish for prawns and scallops with otter trawl gear. A further 210 boats are licensed to fish for prawns in inshore and estuarine waters with beam trawl gear. Beam trawl activity is based mostly between Rockhampton and Moreton Bay, and a large part of this area is outside the World Heritage Area.

The proposed management arrangements for the east coast trawl fishery have recognised several important issues such as the capping and reduction of effort; the reduction of bycatch through the introduction of bycatch reduction devices; and preventing the capture of turtles by the immediate introduction of turtle excluder devices in critical nesting and feeding areas. The progressive introduction of bycatch reduction devices, including turtle excluder devices, throughout Queensland in the next few years is also being considered. Other issues are the introduction of vessel monitoring systems to provide a much more accurate picture of fine-scale trawl effort and to improve compliance, and management options to minimise the impact of trawl nets on vulnerable seabed flora and fauna. Most of these issues are being addressed in the development of the new Trawl Fishery Management Plan.

Both spatial and seasonal closures under the fisheries management regime and the zonal management system for the Marine Park apply to the trawl fishery. Spatial closures are intended to protect fisheries habitat such as inshore seagrass beds or reserve areas from extractive use. The area of the Great Barrier Reef lagoon where trawling is prohibited is approximately 10%, of which 40% is in the Far Northern Section of the Marine Park. Apart from nearshore areas, much of the lagoon south of Princess Charlotte Bay is available for trawling. A much larger proportion, over 50%, of the inter-reefal areas is not available for trawling.

Seasonal closures also apply in some areas and are designed to minimise the capture of adolescent prawns recruiting to the fishery and reaching a commercial size before fishing commences. For example,trawling is prohibited north of Cape Tribulation between 15 December and the end of February. For more information on the trawl fishery, see *Environmental Status – Inter-reefal and Lagoonal Benthos.*

How Does a Bycatch Reduction Device Work?



In the top diagram the trawl net has no bycatch reduction devices fitted. All animals that enter the net are caught in the cod end, including prawns, turtles and unwanted fish species. In the bottom diagram, the trawl net has two types of bycatch reduction devices fitted. The turtle excluder device stops turtles from entering the cod end and forces them out through a flap on the trawl net. Because fish have a tendency to swim against a current, the fish eye allows them to swim out through the top of the trawl net and avoid capture in the cod end. Even with the bycatch reduction devices fitted, prawns are still caught in the cod end.

Reef Fish Line Fishery

The coral reef fish line fishery relates to fishing for fish species in tropical coral reef or shoal habitats using hook and line gear. The fishery has three major sectors: commercial fishing, charter fishing and recreational fishing. There is some indigenous fishing in northern areas of the Great Barrier Reef, but there is little information about those activities. Under the Marine Park zoning plans, there is no distinction between commercial and recreational operations in this fishery

Fishing for coral reef fish using a hook and line is a popular pastime in the Great Barrier Reef World Heritage Area.

The main target species for all sectors of the fishery are coral trout, red-throat emperor, red emperor, other cods, wrasse, snappers, and emperors. Pelagic species such as Spanish mackerel are also caught. A greater diversity of species is targeted in the Capricorn–Bunker region of the Great Barrier Reef than elsewhere. The biology of these species, apart from the coral trout, is not well understood.

The principal commercial licence for the fishery (L2) includes 251 operators. There are a further 1563 commercial operators having a more limited licence to participate in the fishery (L3). Typically, under the L2 reef fishing licence, fishing is undertaken from one to four dories, which work from a main vessel. Restrictions apply to the length of primary (20 m) and tender vessels (7 m). The L3 licence allows fishing from either the main vessel and/or one dory. The fishing gear is relatively standard with a single hand line of 70 to 120 pounds (about 32 to 55 kg) breaking strain. Restrictions apply on the number of hooks used and there are minimum size limits on the major species.

There is considerable diversity in the commercial fleet in terms of species targeted, crew skills, and annual per-boat catch and effort. In recent years, developments in the way in which fishers can retain product and the rapid emergence of new markets for live reef fishes have increased significantly the profitability of the fishery. Since 1992, the price of whole and filleted frozen coral trout has increased by nearly 200%, and more recently, fishers have been receiving prices of $18–45 per kg for live coral trout.

The charter and recreational sectors also use hand-held gear (rods and hand reels). A bag limit of 30 fishes from 26 reef fish species, with certain species sub-limits, applies to recreational fishers. Recreational fishers are not permitted to sell their catch. Charter boat clients on fishing charters in excess of 48 hours' duration may possess double the normal recreational bag limit. In 1998, 270 charter vessel operators held permits to undertake fishing trips. Of these operators, 211 were authorised to engage in offshore fishing.

In a recent telephone survey of 21 000 households in Queensland, it was estimated that 34% of Queenslanders fished at least once per year, but only 6% of those were in fishing clubs. These figures were similar to results from a 1986 survey by the Australian Bureau of Statistics indicating that approximately 30% of Queenslanders fished at least once a year and about 34 000 people fished offshore waters in the Great Barrier Reef Region at least once a year. It has been estimated that 270 000 fishing trips were made in private trailer boats in the Great Barrier Reef Region in 1989–1990, but that only 5.4–13.5% of those were to 'open waters'.

There are a number of management issues being considered by the Reef Fish Management Advisory Committee. They include emerging new fishing effort, latent effort in the fishery and targeting of fish spawning aggregations. A review of the management measures for the reef fish line fishery is nearing completion and new measures will be implemented by statutory fishery management plans.

Reef closures

The importance and potential benefits for fisheries management of reef closures in the Marine Park have often been debated. Recent literature has espoused the use of spatial and temporal reef closures as an effective mechanism for protecting coral reef fish populations, having benefits for the fishery beyond more conventional management of coral reef fisheries.

The potential advantages of marine protected areas include the protection of spawning stocks, the provision of recruits or larvae to replenish areas outside reserves, enhancement of catch in adjacent unprotected areas through emigration, and minimal requirements for information on the biology of stocks, and ease of enforcement. There is strong evidence that marine reserves protect a critical spawning stock biomass. It is difficult to determine the possible maintenance or enhancement of yields in adjacent areas through the emigration of larvae or the post-settlement movement of juvenile or adult fishes.

In the Marine Park, numerous studies have attempted to assess the effect of reef closures on the abundance of the major target species of the reef fishery. Many of these studies have failed to detect significant differences in total fish population densities of the major species of cod, snapper and emperor, with densities generally differing by less than 15% between open and closed reefs. However, several studies have found that population size and structure tended to be consistently different between open and closed reefs. Two studies in particular found that standing stocks of coral trout can be reduced rapidly when reefs are opened to fishing after several years of protection. One study found that the mean densities of legal size coral trout increased markedly during the period of closure. This increase was driven substantially by a strong cohort of settlement in the early years of the reef closure.

From the evidence to date, reef closures can protect reef fish communities and may have significant benefits for the reef fishery in the Great Barrier Reef. However, the designation of reef closures always is controversial because fisheries managers and industry regard closed areas as a cost to the fishery. The full economic implications of closures on the fishing industry are difficult to ascertain because the fishery has a number of sectors. The potential for mobilisation of considerable latent effort in the commercial fleets is considerable. A diverse range of species is available to the fishery and changing markets will affect fishing behaviours and the focus on some species. There is a dearth of data on the economic and motivational forces driving each sector of the fishery.

Inshore Mesh Net Fishery

Two types of netting are associated with this fishery: beach seining and mesh netting, and set net fisheries. Both components of the fishery are generally undertaken in coastal rivers and creeks, estuaries and foreshores extending to less than 0.5 km from low water mark. Beach seining targets mullet, whiting, flathead and bream. Set netting targets fishes such as barramundi, salmon and grunter, which do not travel so much in schools.

The restrictions placed on the net fishery by the fisheries management agencies are limited entry licensing plus a maximum length of net and minimum mesh size. There is a minimum size on the major fish species taken and also a maximum size limit on some species. A closed season from November to February exists for barramundi. Spawning zones also exist at the mouths of some rivers and some estuaries are closed to commercial netting.

The major issues in this fishery are the catch of non-target species and the incidental capture of protected or endangered species such as turtles, dugongs, and dolphins. Also, there are questions of resource allocation between the various sectors which fish in these inshore and estuarine areas.

There is concern over the effects of net fishing on the biodiversity of coastal, river and estuarine systems. Currently, a project being run by the Queensland Department of Primary Industries and the Australian Institute of Marine Science is looking at bycatch in these fisheries with the aim of determining whether or not this concern is justified.

In the World Heritage Area certain areas cannot be net fished under Great Barrier Reef Marine Park and State Marine Park regulations. In response to the decline in dugong numbers in the southern Great Barrier Reef, Dugong Protection Areas were designated in 16 areas south of Cooktown. Within Dugong Protection Areas, a number of bans or restrictions on mesh netting practices have been implemented to minimise the risk of dugong capture. The impact on the fishing industry of the management decisions relating to dugong conservation was specifically recognised, including consideration of appropriate payments to fishers directly affected. Further details on Dugong Protection Areas can be found in *Management Status – Threatened Species*.

Harvest Fisheries

The Queensland Fisheries Management Authority is the lead agency responsible for the management of harvest fisheries. The Great Barrier Reef Marine Park Authority has separate legislative assessment and permitting requirements in relation to commercial harvest or 'collecting' fisheries under the *Great Barrier Reef Marine Park Act 1975*. These fisheries include marine aquarium fishes, trochus, bêche-de-mer, coral and specimen shells.

A Harvest Fishery Management Advisory Committee was recently established under the *Fisheries Act 1994*. Its purpose is to facilitate the development of management plans for each relevant fishery and provide an effective forum through which to address management issues across the harvest fisheries. The Marine Aquarium Fish and Coral Collecting Working Group is currently developing a public discussion paper. The Trochus and Bêche-de-mer Working Groups will shortly commence the same process.

Marine aquarium fishes

The marine aquarium fish fishery is managed by input controls (controls on apparatus, number of participants, number of divers, area of operation). Commercial and recreational fishers are limited to collection of fishes by hand or by using lines or cast, scoop or mesh nets, and underwater breathing apparatus may be used. It is a limited entry fishery with less than 70 authorised commercial fishers throughout Queensland. Recreational aquarium fish collection also occurs, however only limited catch and effort information is available.

The marine aquarium fish fishery was last reviewed in 1994. Interim management arrangements currently before the Marine Aquarium Fish Working Group include issues such as cost recovery through industry fees, transferability of authorities, licensing, removal of latency, zoning of the fishery and amendments to the application process, including entry criteria.

There are concentrations of collectors and effort in certain areas, particularly offshore Cairns and in the Whitsundays. Concentrations of collectors are dependent on overseas air export facilities (mainly located in Brisbane and Cairns) and require endemic species in large enough numbers to export economically or to sell to hobbyists.

Only limited assessment of catches of marine aquarium fishes has occurred and there is an absence of a reliable long-term historical catch and effort dataset. Species- and site-specific data returns are required to adequately monitor the fishery. The management planning process will investigate listing of endemic species (e.g. pineapple fish) in the logbooks to enable adequate monitoring.

Trochus

The fishery for the mollusc trochus is managed through limited entry and a quota system. Only one species is commercially collected in Queensland. Trochus authorities are transferable. This transferability of authorities is a key management issue.

There is currently a 300-tonne total allowable catch set in the *Fisheries Regulation 1995* for the east coast fishery, with 250 tonnes allocated each year to existing authority holders by way of a condition of each individual authority. There are six trochus authorities for the east coast fishery. The Queensland Fisheries Management Authority is in the process of converting the total allowable catch to a 'unit' format that removes the idea of unallocated quota. A review of two previous stock assessments has recently been commissioned.

Bêche-de-mer

Bêche-de-mer is a quota managed fishery. There are three main species of sea cucumbers collected. The current bêche-de-mer total allowable catch for the east coast is 380 tonnes allocated to 18 collectors.

There is little information available about the biology of sea cucumbers and recruitment rates are largely unknown. Research has been initiated on the principal species to enable better stock assessments to be undertaken. Some species not yet harvested could become high-value, high-demand species (e.g. greenfish has recently been discovered to have pharmaceutical properties).

Coral

Coral is an input and output control (quota) managed fishery. There are approximately 60 coral collecting sites, each of which can have an annual harvest of up to four tonnes. Actual harvest levels are below 50 tonnes landed annually and the prospect of landing the entire total allowable catch appears unlikely. Harvest levels are clearly sustainable, although conflicts arise between harvesting and coral viewing at some accessible sites.

In the coral collection fishery it was previously considered that there was a large fast-growing resource of targeted coral. However, the collected species have changed and conservation issues are taking a higher profile within the broader community.

The industry has progressed from the curio trade to the aquarium live coral trade. Collectors are now targeting species never previously collected. There is a concern that rarer species could be targeted and overcollected. Because of their accessibility in all weather conditions, commercial coral collectors want access to fringing reefs which are the environments least able to cope with collection (except perhaps for *Pocillopora* which is virtually no longer collected).

Specimen shells

There are a total of six authorities. The collectors have been changing from hobbyists to commercial collectors.

The Queensland Fisheries Management Authority permits specify 10 of any one species to be taken annually. The intent is for a specimen collection fishery, not a large-volume collection fishery that exports overseas. 'Limited collecting' (i.e. a maximum of five specimens per species to be taken in any 28-day period) applies 'as of right' in Marine Park General Use zones, but is almost impossible to enforce.

SUMMARY

Commercial, recreational and charter boat fishing occur in the World Heritage Area subject to Great Barrier Reef Marine Park zoning plans. The management of most fisheries in the World Heritage Area is the responsibility of the Queensland Government through the Queensland Fisheries Management Authority.

The Great Barrier Reef Marine Park Authority works closely with the Queensland Fisheries Management Authority to ensure that fisheries and Marine Park management planning are complementary. Management Advisory Committees have been established for all of the major fisheries to provide stakeholder input into fisheries management.

The trawl fishery is concentrated in the Great Barrier Reef lagoon and targets prawns and scallops. A Trawl Fishery Management Plan is currently under development, addressing issues such as latent effort, reduction of bycatch and prevention of incidental capture of turtles. Areas of seabed fished by commercial trawling are likely to be subjected to significant impacts and management options to minimise these impacts on the inter-reefal and lagoonal benthos are being considered.

The reef fish line fishery supports commercial and recreational operations, and targets cod, snapper and emperor. Management issues include latent effort, emerging new fishing effort and developing strategies to ensure that fishing is ecologically sustainable. Reef closures to fishing can protect fish populations but incur costs for the fishing industry. A review of current fishery management measures is nearing completion. New measures will be implemented by statutory fishery management plans.

Management issues for the inshore mesh net fishery include bycatch and incidental capture of turtles, dugongs and dolphins. Netting restrictions apply in Dugong Protection Areas. Other fisheries in the World Heritage Area include marine aquarium fishes, trochus, bêche-de-mer, coral and shells. Most of these fisheries are managed by harvest quotas and management plans are currently under development.

Trawling is a major commercial fishery in the Great Barrier Reef lagoon, targeting prawns and scallops.

OVERVIEW

Tourism is the principal industry in the Great Barrier Reef World Heritage Area, with an approximate annual value in excess of $1 billion. Visitation to the Great Barrier Reef in 1997 was recorded at 1.6 million visitor-days. The volume and profile of tourism use of the World Heritage Area has changed significantly in the past 20 years. As marine tourism has expanded and diversified, a more strategic and integrated management approach has been adopted, accounting for both individual and cumulative impacts of tourism use.

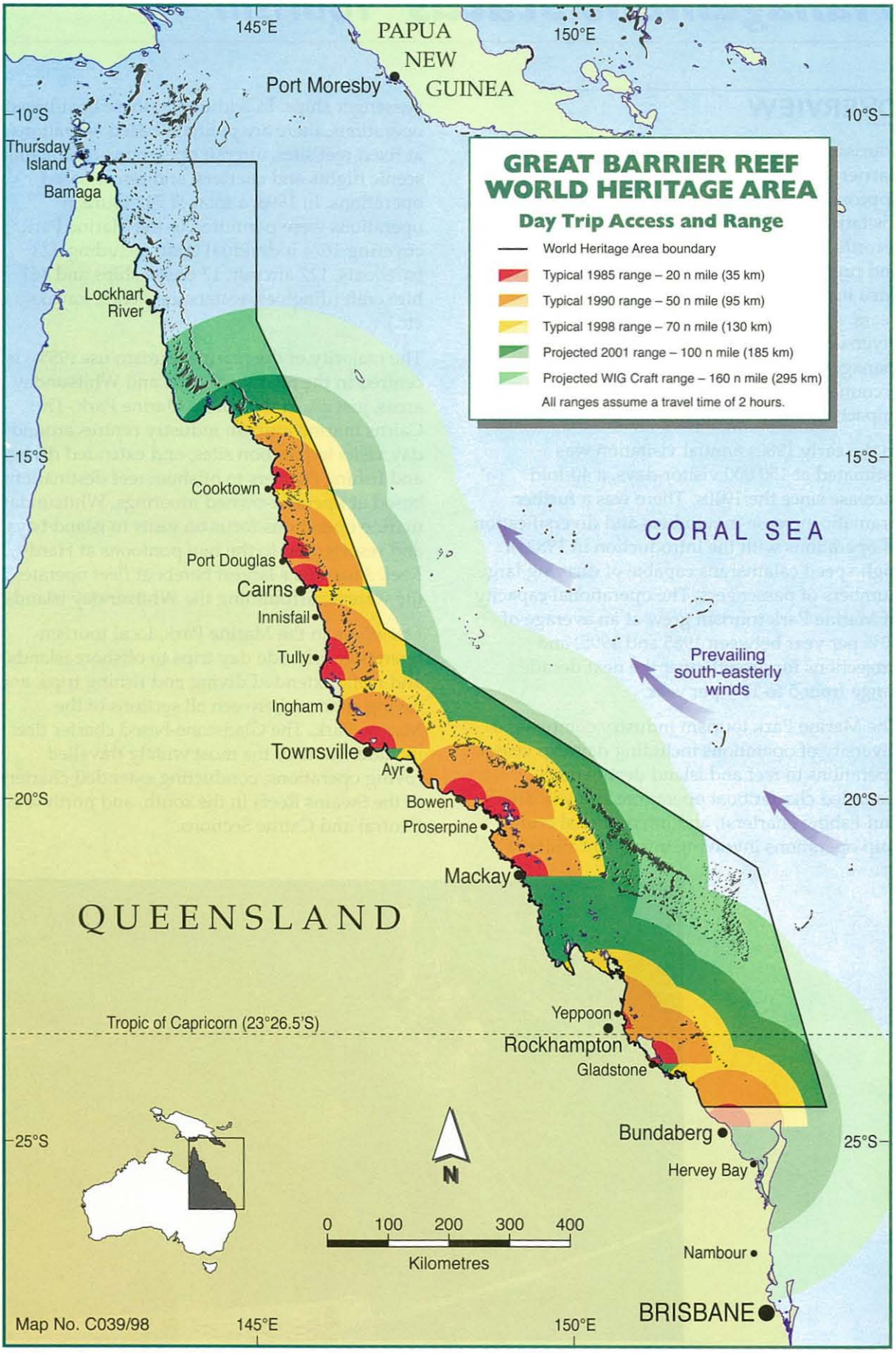
In the early 1980s annual visitation was estimated at 150 000 visitor-days, a 40-fold increase since the 1940s. There was a further dramatic increase in numbers and diversification of operations with the introduction in 1982 of high-speed catamarans capable of carrying large numbers of passengers. The operational capacity of Marine Park tourism grew at an average of 10% per year between 1985 and 1995, and projections for growth over the next decade range from 5 to 11% per year.

The Marine Park tourism industry comprises a diversity of operations including day-trip vessel operations to reef and island destinations, extended charter boat operations (mostly dive and fishing charters), and international cruise ship operations involving infrequent visits of passenger ships. In addition to these boat-based operations, there are pontoon-based operations at fixed reef sites, aircraft operations conducting scenic flights and charters, and resort-based operations. In 1998, a total of 742 tourism operations were permitted in the Marine Park, covering 1674 individual craft, including 328 bareboats, 127 aircraft, 17 cruise ships and 461 hire craft (dinghies, watersports craft, kayaks etc.).

The majority of the marine tourism use (95%) is centred in the offshore Cairns and Whitsunday areas, just 5% of the whole Marine Park. The Cairns marine tourism industry centres around day visits to pontoon sites, and extended diving and fishing charters to offshore reef destinations, based at operator-owned moorings. Whitsunday marine operations focus on visits to island bays and resorts, and to the two pontoons at Hardy Reef. Australia's largest bareboat fleet operates in the waters surrounding the Whitsunday islands.

Elsewhere in the Marine Park, local tourism operations provide day trips to offshore islands and reefs, extended diving and fishing trips, and roving charters between all sections of the Marine Park. The Gladstone-based charter fleet includes some of the most widely travelled roving operations, conducting extended charters to the Swains Reefs in the south, and north to the Central and Cairns Sections.

Introducing visitors to snorkelling is one of a wide range of activities provided by the Marine Park tourism industry.



As boats become faster, the range of day trip operators increases. In 1985 the typical range was only 35 km, but in 1998 it was 130 km and the projected range for the year 2001 is 185 km. With the development of wing-in-ground-effect craft (WIG craft) the range may extend as far as 295 km.

CURRENT STATUS

Tourism use in the Great Barrier Reef Marine Park is managed jointly by the Great Barrier Reef Marine Park Authority and the Queensland Department of Environment and Heritage, within the statutory framework of zoning plans, management plans and permits. The zoning plans provide little direction on tourism activities other than defining where fishing and collecting are allowed and, in the case of the Cairns Section, defining areas where the installation of structures such as pontoons may be considered.

The zoning provisions require all marine tourism operations to have a permit, subject to assessment against set criteria. Until recently permits have been used as the principal tool for management of tourism activities in the Marine Park. Permit applications have been assessed and granted on a 'first-come, first-served' basis with conditions specific to the area of operation and type of activity. Permit tenure is generally six years.

The need for a shift away from permits as the prime management tool for marine tourism was acknowledged in a major review of the Marine Park permit system in 1993. The review recommended that marine tourism management be achieved through a combination of tools and strategies including simplification of permits, greater emphasis on site management and control of impacts, and better use of plans, education, training and codes of practice. The focus of future management will move away from managing individual operations to place-based management with emphasis on preventing and managing impacts. Integral to the success of this approach will be continued consultation with stakeholder groups during the period of change.

Marine Park tourism operators are subject to an Environmental Management Charge which is currently equivalent to $4 per visitor per day for standard tourist operations such as day trips, extended charters and bareboat hire. The charge applies to all commercial operators who hold Marine Park permits. Commercial operators are required to keep a logbook of operations and must supply quarterly returns.

MANAGEMENT ISSUES

Impacts of Marine Tourism Use

The impacts of marine tourism use can be broadly categorised as ecological, social and cultural. Ecological impacts include physical effects on the environment and threats to conservation values including damage to coral through poor anchoring and reef walking, disturbance to nesting birds and vegetation on cays and sand dunes, interference with whales, dugong and turtles, and change of water quality through discharge of vessel sewage and bilge water. Of particular concern is the unsustainable level of anchor damage which has occurred in heavily used areas such as the Whitsunday fringing reefs.

Ecological impacts of tourism are minimised or eliminated through the permits process of the Great Barrier Reef Marine Park Authority and the Queensland Department of Environment and Heritage. Great care is taken to locate tourism operations and restrict activities such that ecological impacts are as small as possible. This is verified through the use of environmental monitoring programs (for more details, see *Management Status – Monitoring*). While some impacts may occur at heavily used sites, these sites represent a small fraction of the area of the reef in question and the number of reefs with heavily used sites is a small fraction of the total number of reefs in the World Heritage Area.

Social impacts include effects on the experience of other reef users, possibly leading to displacement through disturbance and crowding. As tourism use of an area increases, the opportunities for a peaceful recreational experience may decrease. Cultural impacts affect the traditional and historic values of an area and may displace recreational users and traditional hunters.

Unused Permits

Examination of logbook data collected through the administration of the Environmental Management Charge has shown that a substantial number of tourist program permits are not being used. In 1994–95, 25% of all permitted tourism operations did not operate in the Marine Park, whilst 46% of those permitted to operate in the Cairns Section did not operate in the area in the same period. Since January 1996 over 50% (1189) of all craft permitted to operate in the Marine Park were not used at all. This unused capacity of permits is of concern because actual marine tourism use could potentially increase fivefold without the issue of any new permits.

Fast boats and permanently moored pontoons cater for large numbers of day visitors to the Reef.

Changes in Market Trends

The tourism industry has grown and changed significantly over the past 20 years and is expected to continue to change with improvements in technology and changes in the market forces. The extended range of operations due to increased vessel speed spreads the impacts of tourism and adds pressure to already stretched enforcement capabilities. For planning to be proactive it must consider potential changes to transport, such as wing-in-ground-effect craft, capable of surface speeds of 70–80 knots, currently being investigated by Cairns-based operators.

The demand for tourism operations is also expected to change with changing trends in domestic and international tourism. A recent social survey predicts a change in the demand for operations as the marine tourism industry grows and 'matures'. Currently many first-time visitors to the Reef take a day trip to a pontoon with large numbers of other visitors. As the industry attracts higher numbers of repeat visitors the demand for smaller specialised tours at more varied destinations (i.e. small roving operations) is likely to increase. This demand will result in pressure on a broader range of sites.

Displacement and Loss of Opportunity

The rapid growth of tourism has resulted in displacement of traditional and recreational users at some sites, particularly in the Cairns and Whitsunday areas. The increasing intensity of use at sites where pontoons and moorings have been installed reduces the opportunity for small tourist operations and recreational users to access more remote experiences free from other users. The Great Barrier Reef Marine Park Authority recognises a need to provide a diverse range of experiences and uses in order to meet its obligations to present and transmit the World Heritage values to present and future generations.

FUTURE DIRECTIONS

Future management of marine tourism will be based on:

- strategic planning to establish a clear direction for managing marine tourism,
- direct management to establish well-defined, enforceable and effective management controls to protect the values of the Marine Park,

- self-regulation by the industry to encourage, assist and promote environmental responsibility and professional presentation of the Reef within the marine tourism industry, and
- active partnerships to encourage the industry and other stakeholders to be active partners in Marine Park management.

Strategic Planning

The Great Barrier Reef Marine Park Authority is developing a Reef-wide approach to managing tourism use throughout the whole of the Marine Park. It will provide a strategic framework for future management, taking into account the cumulative impacts of tourism use. The planning process will identify natural, social, cultural and heritage values which could be affected by tourism and identify methods to protect these values.

The strategies will be implemented through changes to legislation and policy, statutory plans of management, and education. The first plans of management, for the Cairns Area and the Whitsundays, were gazetted on 22 June 1998, incorporating provisions for protection of the values of both areas, and for managing tourism and recreation activities. These plans introduce management strategies such as use settings, limits to use for some sites, recognition of historic use of sites by tourist operators, and a booking system for access to some sites or areas. Similar strategies may be applied through other plans currently being developed for the Hinchinbrook and Capricorn–Bunker areas.

Direct Management

The simplification of the permit system will begin with the implementation of the Cairns Area and Whitsundays Plans of Management, and will be extended to other areas as planning is completed. Individually crafted permits will mostly be replaced with a range of standard permits based on a class assessment. Large and complex tourism proposals and developments will still require individual assessment. An independent committee will be established by the Great Barrier Reef Marine Park Authority to assist with the process of transition from existing permits to the new system.

Industry Self-regulation

Progress towards greater self-regulation has been made through the adoption of codes of conduct and compliance with best environmental practices. A number of industry associations have been effective in regulating their activities through their own codes.

Many operators who recognise the importance of interpretative activities employ staff with appropriate skills to inform passengers about the Reef and best practices. The tourism industry training programs developed by the Great Barrier Reef Marine Park Authority for Marine Park tour operators in 1996 will continue to be implemented and reviewed, and operators encouraged to facilitate staff training through this program.

With the marine tourism industry and other stakeholders, the Great Barrier Reef Marine Park Authority is investigating systems of accreditation for marine park guides and operators. Authority staff are working closely with the Whitsunday bareboat industry to develop a staff training program which will form the basis of future accreditation for this industry.

Active Partnerships

Formal processes for community consultation are already established through coastal Regional Marine Resources Advisory Committees with representation from all stakeholder groups. As part of the critical issues approach to Marine Park management, the Great Barrier Reef Marine Park Authority is to establish an expertise-based Reef Advisory Committee to advise the Authority on issues related to management of tourism and recreation. The Great Barrier Reef Consultative Committee will continue to fill a more strategic advisory role to the Authority.

Tourism industry members are continuing to assist managers and researchers with site monitoring and visitor surveys in order to gain a better understanding of the cumulative impacts of tourism. Representatives of the Whitsunday dive industry, the Order of Underwater Coral Heroes, have volunteered professional diver support for the reef protection program. The Cairns marine tourism industry is involved in the development and implementation of site monitoring systems through the 'Eye on the Reef' program.

SUMMARY

Tourism use of the Great Barrier Reef World Heritage Area has markedly increased over the past 20 years. Most of the marine tourism use is concentrated in two areas which cover only 5% of the Marine Park. All tourist operations in the Marine Park require a permit and commercial operators are subject to the Environmental Management Charge.

The increase in marine tourism use has challenged the adequacy of existing management arrangements and created a number of problems such as assessing cumulative impacts at heavily used sites. The Great Barrier Reef Marine Park Authority together with the Queensland Department of Environment and Heritage and the marine tourism industry are now introducing a more strategic and integrated management approach.

The focus of future management will move away from individual operations to place-based management with greater emphasis on preventing and managing impacts, and better use of education, training and codes of practice. The permit system will be simplified, with replacement of individually crafted permits by a range of standard permits based on a class assessment. Integral to the success of this new approach will be continued consultation with stakeholder groups during the period of change and beyond.

OVERVIEW

Threatened species management in the Great Barrier Reef World Heritage Area derives from Australia's international obligation to ensure the World Heritage Area's protection, conservation and transmission to future generations. The long-term vision is that the World Heritage Area will maintain its diversity of species and habitats, and its ecological integrity and resilience. Management agencies are therefore committed to paying special attention to ensure the recovery and continuing persistence of species whose existence is threatened. A key indicator of the success of management of the World Heritage Area is the success in managing its threatened species.

The goal is to pay special attention to conserving rare and endangered species by:

- identifying species which are endangered in the World Heritage Area and threats to their survival,
- developing and implementing appropriate coordinated management actions, and
- developing and implementing appropriate coordinated management actions in the World Heritage Area for species which are globally endangered.

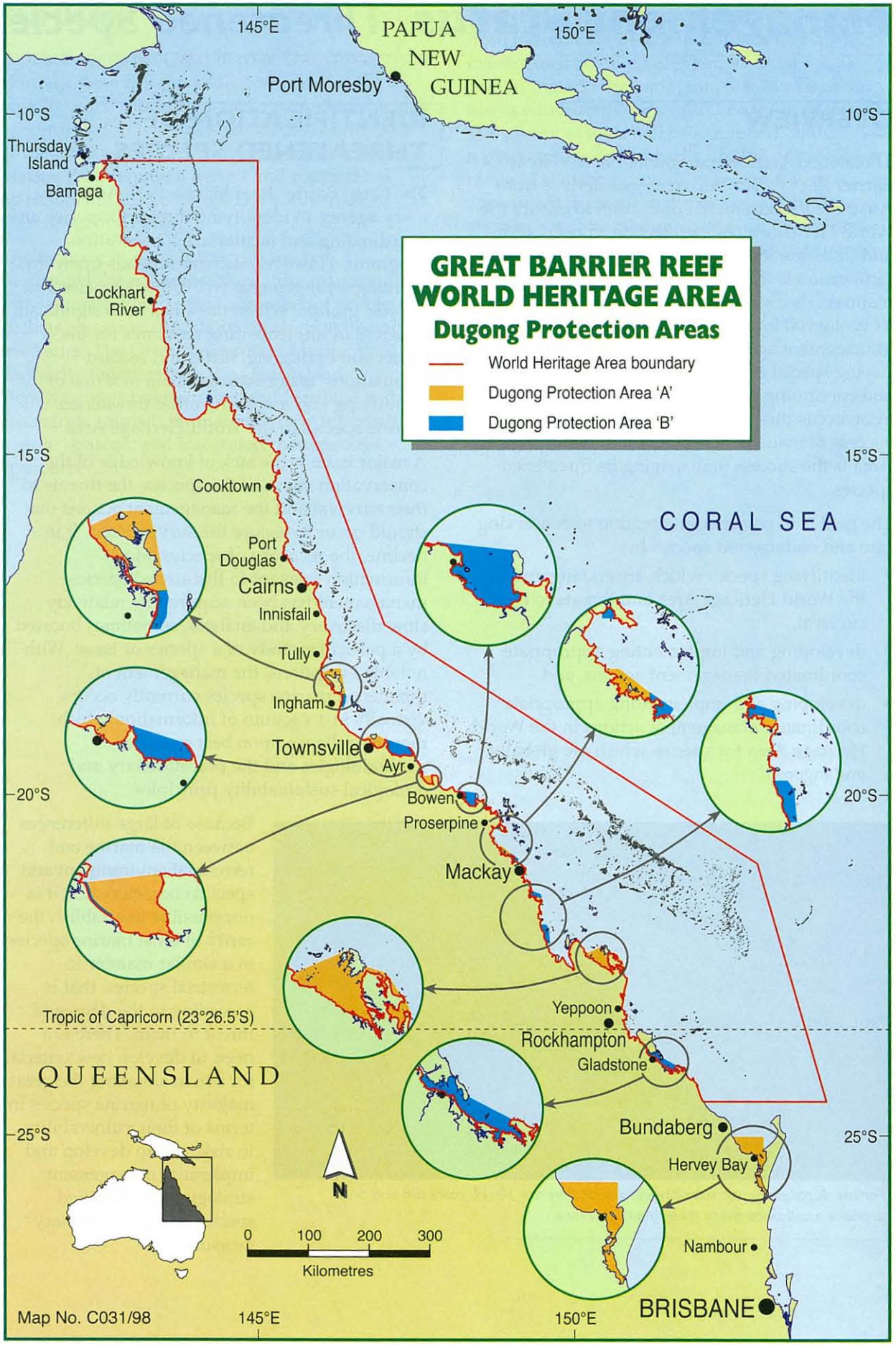
IDENTIFICATION OF THREATENED SPECIES

The Great Barrier Reef Marine Park Authority is a key agency in identifying threats to species and coordinating and facilitating conservation programs. However, success depends upon close working arrangements with other agencies and interest groups. Whilst there has been significant progress in implementing measures for the protection of dugong, turtle and seabird populations, major issues remain in terms of identifying and managing other threatened marine species in the World Heritage Area.

A major issue is the lack of knowledge of the conservation status of the species, the threats to their survival and the management actions that should occur to ensure the survival and, if in decline, the recovery of species. Most information relevant to threatened species management has been acquired by relatively slow discovery and analysis, sometimes boosted by a particular study of a species or issue. With notable exceptions, the management of threatened marine species currently occurs virtually in a vacuum of information which requires reliance upon best practice methodologies and the precautionary and ecological sustainability principles.

Female dugongs do not start breeding until they are 10–17 years old and only produce a calf once every three years or more.

Because of large differences between the marine and terrestrial environment and species characteristics, it is not possible to establish the rarity of most marine species in a similar manner to terrestrial species, that is according to the degree of threat to them. There is a need to develop new criteria for use in assessing the great majority of marine species in terms of their vulnerability to risk, and to develop and implement management strategies for identified species as a precautionary measure.


GREAT BARRIER REEF
WORLD HERITAGE AREA
Dugong Protection Areas
World Heritage Area boundary
Dugong Protection Area 'A'
Dugong Protection Area 'B'
145°E
150°E
PAPUA
NEW
GUINEA
Port Moresby
10°S
15°S
20°S
25°S
Thursday Island
Bamaga
Lockhart River
Cooktown
Port Douglas
Cairns
Innisfail
Tully
Ingham
Townsville
Ayr
Bowen
Proserpine
Mackay
Yeppoon
Rockhampton
Gladstone
Bundaberg
Hervey Bay
Nambour
BRISBANE
CORAL SEA
QUEENSLAND
Tropic of Capricorn (23°26.5'S)
N
0 100 200 300
Kilometres
Map No. C031/98

In the World Heritage Area, the species which are considered to be threatened include the dugong, marine turtles, and some whales and dolphins. There are also a number of birds and island plant species which are considered to be rare or threatened. For more information, refer to the relevant *Environmental Status* sections for these groups.

CURRENT STATUS

Dugongs

In 1994, the Great Barrier Reef Marine Park Authority released a conservation strategy for turtle and dugong in the Marine Park in response to concern about their status. The strategy was developed in consultation with government agencies and interest groups. It specified 47 strategies to enhance protection of the animals and many have since been implemented in part or whole.

Management actions have included the preparation and proclamation of a plan of management for dugong in Shoalwater Bay, the most important and most undisturbed habitat of the species remaining in the southern Reef. A considerable education and extension program by Marine Park management agencies and stakeholder groups has enhanced public understanding of the situation and sought public assistance in reducing risks to dugongs. There has also been enhanced enforcement of restrictions on net fishing and boating to further the protective measures.

Management action culminated in 1997 with a number of decisions by the Great Barrier Reef Ministerial Council, comprising Ministers of the Commonwealth and Queensland Governments. A major decision was to establish 16 Dugong Protection Areas comprising 6353 km^2 in total. Other decisions included modification of the use of fish netting and increased surveillance and enforcement. The impact of the decisions on the fishing industry was to be minimised including appropriate payments to fishers directly affected.

The Ministerial Council decisions were made on the basis of scientific and fishery management evidence. They were taken to enhance the prospect of recovery and conservation of dugong numbers in the region south of Cooktown. The Council undertook to keep the measures under ongoing review to ensure their effectiveness in the recovery and conservation of dugong.

The establishment of the Dugong Protection Areas was a milestone in efforts to save the dugong in the southern Great Barrier Reef and Hervey Bay regions. The areas chosen as Dugong Protection Areas were those with the most dugongs and/or extensive seagrass habitat. A two-tiered system was established comprising Zone 'A' and Zone 'B' Dugong Protection Areas. Amendments to implement the system have been made to Queensland fisheries legislation and are in train under the Queensland *Nature Conservation Act 1992*.

Zone 'A' Dugong Protection Areas have been established in regions centred on Hinchinbrook Island, Cleveland Bay area, Upstart Bay, the Newry Islands, Ince Bay, Shoalwater Bay, Port Clinton, and Hervey Bay–Great Sandy Strait. These areas represent the most significant dugong habitat in the southern Reef. In the Zone 'A' Dugong Protection Areas relevant forms of mesh netting (i.e. offshore set nets, foreshore set nets and drift nets) that represent a significant risk to dugongs were prohibited in January 1998. In the Hinchinbrook region and Shoalwater Bay, river set nets were also banned. Other netting practices such as ring, seine and tunnel netting (which are not considered to pose a serious threat to dugong) were permitted to continue with some modification. In Hervey Bay–Great Sandy Strait the existing specialised netting practices were allowed to continue with modification to reduce their risk to dugongs.

Zone 'B' Dugong Protection Areas have been established in regions centred on Taylors Beach, Bowling Green Bay, the western foreshore of Upstart Bay, Edgecumbe Bay, Northern Repulse Bay, Sand Bay, Llewellyn Bay, Clairview region, and Rodds Bay. In the Zone 'B' Dugong Protection Areas a number of safeguards and restrictions in relation to mesh-netting practices have been implemented to minimise risks to dugongs.

Indigenous communities have become increasingly involved in the management of dugongs and turtles in the Marine Park. Culturally appropriate structures like Councils of Elders have been established by communities to regulate dugong and turtle hunting. These committees are supported by an education and information program. In response to declining dugong numbers south of Cooktown, indigenous groups agreed to voluntarily cease traditional hunting in the region. After ministerial confirmation that permits to hunt dugongs will not be issued in the region south of Cooktown during the current dugong decline, the Great Barrier Reef Marine Park Authority has ceased to issue permits for dugong hunting in the area.

This turtle was caught in a trawl net that was targeting prawns.

Concern over catch of dugongs in shark nets has led to many nets being replaced with baited hooks. Given the importance of seagrasses as food for the dugong, the management measures taken to protect seagrass habitat will support the dugong conservation program.

The success of recent management decisions and actions on the recovery of numbers will be monitored. However, a positive result in terms of a rise in numbers from actions to date is likely to be unclear for a decade or more, because the dugong is a long-lived, slow-breeding animal. On the other hand, more stringent action will be required if population surveys, carcass strandings, and surveillance and enforcement reports show that unsustainable levels of mortality are continuing, or are likely to be continuing, in the regions. For more information on dugongs, see *Environmental Status – Marine Mammals.*

Marine Turtles

Marine Park zoning and management provide for considerable, but not necessarily sufficient, protection of marine turtles within the World Heritage Area. 'National Park' and other zones of high level protection are declared over 6% of the entire Marine Park and over 24% of reefal and inter-reefal areas. Most islands within the World Heritage Area are national parks under Queensland legislation. Many islands and their adjacent waters are closed to visitation, either permanently or seasonally, under zoning and management plans for the purposes of seabird and turtle protection.

The direct taking of turtles in the Marine Park is restricted to traditional hunting by Aboriginal communities living adjacent to the Park and may only occur with a permit. Permits are issued on a community basis or, in the absence of an identified community organisation such as a Council of Elders, to individuals. No areas currently have a moratorium on the issuing of permits for the hunting of turtles.

Marine turtles are caught incidentally by trawlers on the Great Barrier Reef. The main species are loggerhead, green and flatback turtles. Trawling is not permitted in 20% of the Marine Park (mostly over reef and inter-reef areas). Seagrasses are an important food source and habitat for marine turtles. The main management measures to protect seagrass habitat from trawling are Great Barrier Reef Marine Park Authority zoning plans and Queensland Fisheries Management Authority closures. Within the entire Marine Park 45% of surveyed seagrass beds occur in areas not available for trawling. South of Cooktown the proportion is 62%. There are also seasonal and temporal closures under Queensland Fisheries regulations in various places in the World Heritage Area. A recent appraisal of datasets has identified significant turtle habitats and areas where turtles are at increased risk from capture in trawl nets.

A trawl fishery management plan is now under development by the Queensland Fisheries Management Authority. A substantial reduction in the total take of bycatch in trawl nets has been proposed by the Great Barrier Reef Marine Park

Authority, with targets of a 20% reduction by the end of 1999, 50% by 2005 and, thereafter, a continuous reduction of bycatch. A major action proposed to achieve these targets was mandatory use of bycatch reduction devices, particularly turtle excluder devices, on trawlers operating within the Marine Park.

On present indications, it is likely that the Trawl Fishery Management Plan will require the compulsory use of turtle excluder devices in many areas of the World Heritage Area, including key sites where turtles are at high risk of capture in trawl nets. It will also require the development of a process for minimising impacts upon threatened and endangered species which meets the requirements of conservation agencies by December 1998 and that trawl-induced turtle kill levels be negligible by 2000. For more information on marine turtles, see *Environmental Status – Reptiles.*

Whales and Dolphins

The Queensland Department of Environment and Heritage is implementing a policy for whales and dolphins which was finalised in November 1997. The Great Barrier Reef Marine Park Authority is developing a policy also for whales and dolphins within the Marine Park. Major threats to be included in the policy are whale watching, strandings and carcass handling, lack of knowledge of the species and the impacts upon them, incidental capture in fishing nets, and acoustic pollution. For more detailed information on the management actions to better protect whales and dolphins, see *Environmental Status – Marine Mammals.*

Birds

Many islands and seabird rookeries within the World Heritage Area are closed seasonally or long term to visitation to protect breeding seabirds. Guidelines for managing visitation to seabird breeding islands have been published. Education, surveillance and enforcement are the key to solving many of the issues concerning interactions between people and birds on islands.

The populations of seabirds are monitored on some key islands within each Marine Park region. However, standardised techniques and additional resources to allow for better datasets are required to obtain the long-term information necessary to establish trends in numbers. For more information on birds, see *Environmental Status – Birds.*

Island Species

Most islands within the Great Barrier Reef World Heritage Area are national parks and are managed as such in a highly protective legislative framework. Management programs have been developed to control disturbance of natural communities by introduced species and human activities on most islands. However, resources and staffing for day-to-day management can be insufficient for effective management.

SUMMARY

Maintenance of biodiversity in the World Heritage Area requires that threatened species are identified and protected. In the World Heritage Area, threatened species include the dugong, marine turtles, some whales and dolphins, and a number of birds and island plants. In managing these established threatened species in a complex jurisdictional environment, success depends upon close working relationships between agencies and interest groups.

In response to declining dugong numbers south of Cooktown, the Great Barrier Reef Marine Park Authority recently introduced a dugong conservation program. Sixteen Dugong Protection Areas have been established together with restrictions on fish netting and boating, and greater management focus on protection of the critical seagrass habitat. Incidental capture of turtles in trawl nets will be reduced by the mandatory use of turtle excluder devices, which have been proposed in the Trawl Fishery Management Plan under development by the Queensland Fisheries Management Authority. The Queensland Department of Environment and Heritage is implementing a whale and dolphin policy which addresses issues such as whale watching and incidental net capture.

A major problem for threatened species management is the lack of knowledge on the conservation status of species and the required management actions. There is a need to develop appropriate criteria for assessing vulnerability to risk among the majority of marine species that are currently unassessed.

OVERVIEW

Aboriginal and Torres Strait Islander peoples have significant cultural, historic and economic associations with and interests in the Great Barrier Reef World Heritage Area. Contemporary Indigenous peoples are attempting to retain their cultural association, values and use of the area in the face of increasing pressure from coastal development, commercial fishing, private recreational use and rapidly expanding tourism use.

The European occupation of northern Australia during the last 150 years has significantly affected indigenous demographics, economics and culture. Despite this impact Indigenous peoples maintain their cultural traditions and identity through reinforcing links to land and sea country. Many Indigenous peoples now live in major towns in the region adjacent to the World Heritage Area as well as in the more remote areas of Cape York Peninsula. These people maintain a strong association with the World Heritage Area and actively seek to be involved in the management of the region.

The *Great Barrier Reef Marine Park Act 1975* made no specific reference to Indigenous people but provided for statutory structures and mechanisms for public involvement in Marine Park management. The Government has partly accommodated indigenous interests through the amendment of the Great Barrier Reef Marine Park Act and Regulations. The Act was amended in 1995 to give greater representation of indigenous interests in management. There is indigenous representation on the Great Barrier Reef Marine Park Authority and the Great Barrier Reef Consultative Committee.

Since 1975 the Great Barrier Reef Marine Park Authority has worked with Indigenous peoples to better recognise and accommodate their interests in the management of the region. Aboriginal and Torres Strait Islander interests were recognised as a specific objective of the 25 Year Strategic Plan for the Great Barrier Reef World Heritage Area.

CURRENT STATUS

Indigenous Perspectives on Land and Sea Management

From an indigenous perspective, coastal landscapes and seascapes are part of an integrated cultural domain comprising defined owned clan estates to which affiliated groups belong, and from which they get their identity and customary rights to own and exploit resources. This perspective contrasts with the European concept of coastal and marine systems as separate domains, the common property nature of marine resources and concepts of naturalness.

Aboriginal and Torres Strait Islander groups continue to identify themselves as traditional owners and custodians of marine estates. The recognition of sea rights is not only a matter of identity but also an avenue to claim management responsibility for the protection of cultural heritage and to develop viable economies from the use of marine and coastal resources.

Under the Commonwealth *Native Title Act 1993*, Indigenous peoples are seeking formal recognition of their rights to land and sea. There are currently nine Native Title claims within the Marine Park accepted for mediation by the Native Title Tribunal and one other has been lodged.

Consideration of Indigenous Interests

The Great Barrier Reef Marine Park Authority is addressing indigenous interests through a continual process. Since the late 1980s a number of reports have been commissioned by the Authority to investigate indigenous involvement with and use of the World Heritage Area. All of the reports noted the lack of involvement of Aboriginal and Torres Strait Islander peoples in the management of the World Heritage Area.

Consideration of indigenous interests has been shaped by government policy, legal instruments and increasing indigenous demand for recognition and involvement in management of their areas of interests. There has been an

increase in the number of programs, projects and policy which have given greater recognition of the rights and interests of Indigenous peoples and provided greater opportunities for active involvement in all aspects of the planning and management of the Great Barrier Reef Marine Park.

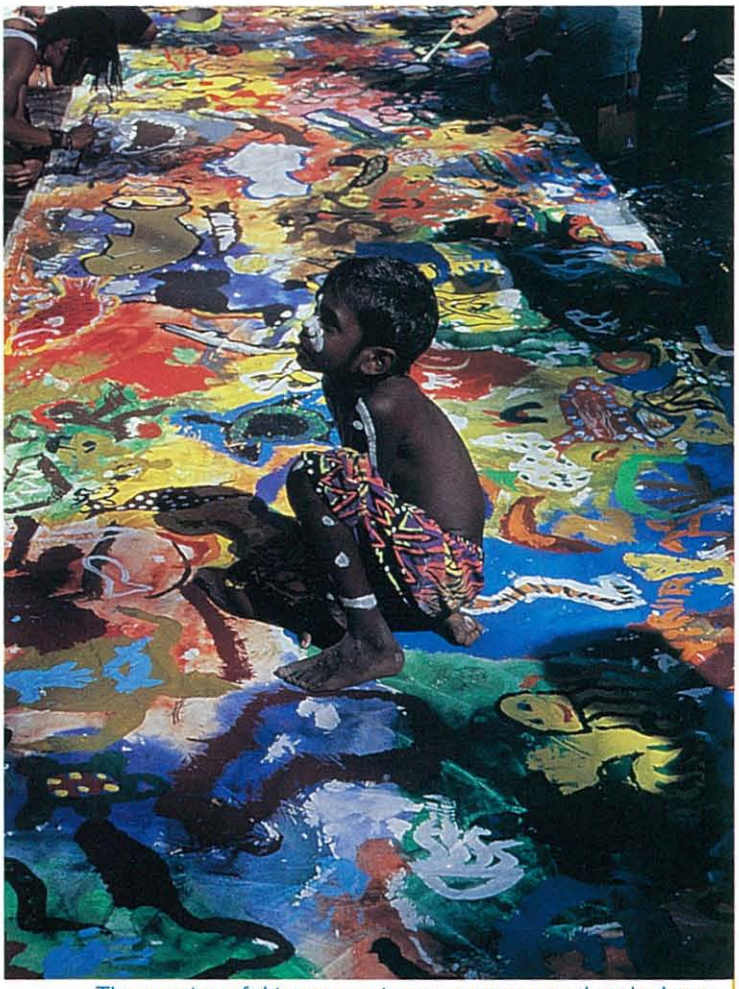
Liaison and a range of negotiation and consultation opportunities have occurred in planning programs, impact assessment procedures, and day-to-day management. During the review of the Far Northern Section zoning plan, a wide range of avenues for indigenous input were provided including a series of community-based workshops where local issues were discussed and planning groups established.

Involvement in day-to-day management has been increased through the community ranger program. This program is a cooperative effort between indigenous communities and a number of agencies, including the Queensland Department of Environment and Heritage and the Great Barrier Reef Marine Park Authority. At least, eight community rangers have been appointed as inspectors under the Great Barrier Reef Marine Park Act.

Aboriginal and Torres Strait Islander communities were involved in the preparation of a dugong and turtle strategy and permit arrangements for the management of traditional hunting by Councils of Elders. Under the Council of Elders concept, the Authority grants permits to the community and the Council of Elders then manages individual hunting permits. This concept has proved successful in the management of dugong populations and the protection of cultural and heritage values at particular locations. There are currently seven permitted community hunting areas in the World Heritage Area.

In response to declining dugong numbers south of Cooktown, indigenous groups agreed to voluntarily cease traditional hunting in the region. The Kuku-Yalanji Conservation Council has developed a conservation program which includes a moratorium on dugong hunting. Cooperative management arrangements are being pursued and a forum of Aboriginal Traditional Owners is planned to consider mechanisms for the development of cooperative management of marine resources within the World Heritage Area.

The Great Barrier Reef Marine Park Authority has developed an Aboriginal and Torres Strait Islander employment strategy based on increased recruitment and retention of Aboriginal and Torres Strait Islander staff. To date, two identified liaison positions have been created and representation among staff has increased from 1% to 5%, the 5% target being representative of the Aboriginal and Torres Strait Islander populations in the Great Barrier Reef region. The Authority's Indigenous Cultural Liaison Unit provides advisory, networking, coordination and training services to facilitate planning, permits and extension work with Aboriginal and Torres Strait Islander peoples, agencies and communities.



The creation of this community sea country mural at the Laura Indigenous Dance Festival was part of the process of involving indigenous communities in Marine Park Planning.

Indigenous perspectives and values have been included in educational and interpretive material (e.g. brochures, newsletters, other publications and videos) and extension and consultation programs with industry (tourism and fishing) and other interest groups in the World Heritage Area. Indigenous interests are represented on regional marine resources advisory committees. The Great Barrier Reef Marine Park Authority has also developed culturally appropriate extension material about the Marine Park and its management for Indigenous peoples.

Cross-cultural awareness workshops have been organised to improve understanding of indigenous perspectives by Great Barrier Reef Marine Park Authority staff. The Authority has also been extensively involved in the design and delivery of tertiary courses on indigenous involvement in resource management.

MANAGEMENT ISSUES

More effective recognition of indigenous interests has been hampered by the difficulty of translating broad policy directions into operational policies and strategies. Implementation of legal changes in decision-making arrangements and development of a framework for indigenous self-management have been limited and long-term funding mechanisms are uncertain.

Recent achievements are unlikely to meet indigenous aspirations for self-determination and a meaningful management role as consistently expressed. For the Great Barrier Reef Marine Park Authority, the issue of governance, which is fundamental to the recognition of indigenous rights and interests in management, is complex. It involves different cultural and legal perspectives of ownership and responsibility for management, consideration of public versus private interest and the need to accommodate indigenous rights with conservation and a multiple use context.

Many issues remain unresolved. Legal uncertainties and the need to reserve positions in regard to Native Title claims over the World Heritage Area may have affected the levels and form of indigenous and Great Barrier Reef Marine Park Authority involvement in policy, planning and management arrangements. It is likely that further developments will occur in relation to Native Title claims in the Marine Park. This may result in a changing relationship between the Commonwealth, the Authority and Indigenous peoples with respect to sea rights over substantial areas of the Marine Park.

Co-management arrangements and heritage zones have been partially addressed though permit assessment. The review of the Far Northern Section of the Marine Park advanced recognition of indigenous interests but requires the development of management plans to give effect to Aboriginal involvement in management. Additional funding for increasing the role of Indigenous peoples in day-to-day management is uncertain. Collaborative research has been undertaken through planning processes although the issue of property rights remains unresolved.

SUMMARY

Aboriginal and Torres Strait Islander peoples have strong historical and cultural associations with the Great Barrier Reef World Heritage Area and are actively seeking involvement in its management. The Great Barrier Reef Marine Park Authority has focused substantial effort over the last ten years in addressing indigenous interests in the Marine Park. Strategies used have included government amendment of legislation, extensive liaison and extension activities, and targeted involvement in planning, impact assessment and day-to-day management.

The community ranger program and the introduction of community permits for traditional hunting have increased indigenous involvement in day-to-day management. The establishment of a dugong conservation program has been supported by a voluntary moratorium on traditional hunting of dugong by indigenous groups in the southern Great Barrier Reef. Resolution of legal uncertainties relating to Native Title claims in the World Heritage Area will affect future management arrangements.

The recognition and integration of indigenous interests and participation in management should be seen as a long-term interactive process involving many players and levels of decisions, only some of which are under the control of the Great Barrier Reef Marine Park Authority. Such process need time and support from the wider community as well as greater awareness of indigenous interests from users of the World Heritage Area.

Management Status

Water Quality and Coastal Development

OVERVIEW

Water quality in the Great Barrier Reef World Heritage Area is principally affected by land-based activities in the adjacent catchments. Land-use activities in the catchments include vegetation modification, grazing, agriculture, urban development, industrial development and aquaculture. For more information on water quality status in the World Heritage Area, see *Environmental Status – Water Quality*.

Beef cattle grazing on the large, dry catchments adjacent to the Marine Park (in particular the Burdekin and Fitzroy) has involved extensive tree clearance and over-grazing during drought conditions. As a result widespread soil erosion and the export of the eroded material, with its associated nutrient content, into the Great Barrier Reef have occurred.

Cropping, particularly for sugarcane, has involved intensive fertiliser use as well as substantial soil erosion. As a result large amounts of nutrients and sediment have been discharged via rivers into the Great Barrier Reef. Pesticide residue input from cotton and sugarcane cultivation may be a localised problem in inshore waters.

Other threats to water quality arise from increasing populations on the Great Barrier Reef coast. Extensive loss of coastal freshwater wetlands through urban and agricultural development has impaired the ability of the coastal zone to filter catchment run-off. Discharge of sewage effluent is a significant local problem in some locations. Urban diffuse run-off from the major coastal cities is a significant but very localised problem. Impact assessment for major coastal developments needs to consider the direct and indirect impacts on the reef environment.

While land-based impacts on water quality are a core concern in relation to coastal development, there is a range of other impacts which also require planning and management in order to effectively ensure the protection of the World Heritage Area. The coastal zone is the location of the majority of marine tourism infrastructure, ports and harbours, and industrial development. Given the multitude of competing uses for the coastline, there is enormous potential for conflict and a need for complementarity between land use and Marine Park planning and management.

The management of the land-based impacts on the World Heritage Area will be difficult as the activities causing the problems lie outside the boundaries of the Marine Park and involve multiple authorities. The 25 Year Strategic Plan for the Great Barrier Reef World Heritage Area identified integrated land and coastal development as an important process in minimising pollutant input from the land to the sea.

Water quality has been identified by the Great Barrier Reef Marine Park Authority as a critical issue for the management of the Marine Park. The management of water quality in the Marine Park involves policy decisions such as that requiring tertiary treatment of sewage, cooperative arrangements between the Great Barrier Reef Marine Park Authority and Queensland Government departments to reduce pollutant inputs, case by case management of activities such as dredging and spoil dumping, and enforcement of Australian Government legislation such as that regulating the dumping of substances from ships. The reduction in nutrient loads entering the Marine Park from coastal catchments is seen as the most important water quality issue facing the World Heritage Area.

CURRENT STATUS

Jurisdictional Issues

The western boundary of the Great Barrier Reef Marine Park is at the eastern extent of Queensland waters (approximately five km offshore) along almost 40% of the coastline. While some of these inshore areas are covered by State Marine Parks, large sections of coastline lie outside both State and Commonwealth marine protected areas. However, along the full extent of the coastline the boundary of the Great Barrier Reef World Heritage Area lies at low water mark.

The major sources of water quality problems for the World Heritage Area originate in the catchments adjacent to the Great Barrier Reef. These catchments lie outside the boundaries of the Marine Park and the World Heritage Area. Thus the *Great Barrier Reef Marine Park Act 1975* provides little scope to control catchment activities which produce run-off which, in turn, may degrade or damage the World Heritage Area. Some power does reside in the Act which provides for 'regulating or prohibiting acts

(whether in the Marine Park *or elsewhere*) that may pollute water in a manner harmful to animals and plants in the Marine Park'. The World Heritage Properties Conservation Act could also potentially be used to regulate catchment land use that may adversely affect the World Heritage Area.

Management of catchment pollution sources is primarily under the control of Queensland state agencies particularly through the *Environmental Protection Act 1994*, administered by the Queensland Department of Environment and Heritage, and the *Water Resources Act 1989*, administered by the Queensland Department of Natural Resources. Local government regulations and plans may also have relevance to urban sources of pollution.

Management of Discharges

Sewage effluents contain many polluting substances including organic matter capable of causing oxygen depletion in receiving waters; suspended solids capable of causing turbidity in receiving waters; micro-organisms (bacteria, viruses, fungi, protozoa, parasitic worms), some of which may be pathogenic; nutrients, particularly nitrogen and phosphorus compounds; toxic trace metals such as lead, cadmium and chromium; toxic synthetic organic substances such as pesticides and solvents; petroleum oil; detergents; biologically active drug residues such as vitamins and steroids; and litter.

While many of these pollutants may cause problems at very local scales the pollutants of major threat to Great Barrier Reef are the nutrients nitrogen and phosphorus. Most of the rest of the substances listed are reduced to low levels by secondary sewage treatment or by prevention of industrial waste entering the sewage system, which is also now mandatory.

Discharges in the Marine Park

Where sewage and other effluents enter the Marine Park directly through an outfall the discharges are regulated through the Great Barrier Reef Marine Park Authority permit system. The options allowed under the present policy for sewage treatment plant discharge in the Marine Park are tertiary treatment (nutrient reduction) followed by marine discharge or land reuse of secondary or tertiary effluent with minimal marine discharge. Most outfalls in the Marine Park now meet the standard.

As no mainland outfalls enter the Marine Park the policy only currently affects island resorts. However any future mainland outfall discharging directly into the Marine Park would also be required to comply with the policy. The present policy has led to some reduction in direct loads of nutrients to the coastal zone.

Urban sewage

As a result of the Marine Park boundaries, mainland urban marine outfalls discharge into waters between the inner boundaries of the Marine Park and the coast. These discharges may still be affecting waters and the ecosystem within the Marine Park but they are not within the direct jurisdiction of the Great Barrier Reef Marine Park Authority for management.

All the large Queensland coastal cities adjacent to the Great Barrier Reef (Cairns, Townsville, Mackay, Rockhampton, Gladstone and Bundaberg), as well as most of the smaller centres (Port Douglas, Innisfail, Tully, Ingham, Ayr, Bowen, Whitsunday and Yeppoon) have secondary treatment sewage systems. These systems have outfalls into coastal streams or the ocean with many using a part of the effluent for land irrigation. Operation of the plants is regulated under the Queensland Environmental Protection Act by the Queensland Department of Environment and Heritage. Standards for discharge are, in principle, for secondary treated effluent.

Problems have resulted from a number of these discharges, particularly in dry season conditions, where discharge into a stream may constitute the total stream flow. Under these conditions algal blooms and anoxia may result. Problems of the Trinity Inlet near Cairns are well known. In some areas with significant urban populations septic systems are still in operation (e.g. most of Magnetic Island, the Mission Beach area). Plans to upgrade these communities to more adequate sewage systems are being implemented.

Municipal authorities are encouraged by both the Great Barrier Reef Marine Park Authority and the Queensland authorities to minimise discharge of sewage effluent to the ocean or to streams that drain into the ocean. The maximum reuse of effluents for irrigation on golf courses, cropping and pasture lands, timber plantations and public parks and gardens is encouraged. This approach is increasingly successful.

Many local government agencies now have policies to maximise reuse of effluents and some have already ceased ocean discharge. For

Run-off from rural areas and urban development affects the water quality within the Great Barrier Reef World Heritage Area.

example, Townsville and Thuringowa cities use over 50% of effluent for irrigation on golf courses and beef pasture land, and plans are in place to increase this proportion. At Yeppoon (Livingstone Shire near Rockhampton) a marine outfall has been removed and all effluent is used for golf course irrigation. The use of wetlands for polishing municipal sewage effluents before reuse or discharge is being investigated at Mossman, Edmonton, Ingham, Townsville, Mackay, Yeppoon and Emu Park.

Industrial discharge

The small number of major industrial sites along the Great Barrier Reef coast are concentrated near Gladstone and Townsville. Only a few of these industries discharge wastewater to the ocean and they are controlled under the Queensland Environmental Protection Act through a licensing system. Plants being constructed in more recent times have been required to have no ocean wastewater discharge (e.g. a zinc smelter currently being constructed south of Townsville).

Aquaculture of saltwater prawns is a small but expanding industry along the Great Barrier Reef coast. Prawns are raised in ponds near the coast and fed processed feed. Unused feed, high in organic matter and nutrients, may be discharged into the ocean through a channel. These nutrient-rich discharges are controlled under the Queensland Environmental Protection Act through licences. More recently new prawn farms are being required to install systems to minimise the volume of discharge and to reduce the pollutant load in the effluent. Systems using pond filtration through beds of bivalves (e.g. oysters and mussels) and algae are being used as well as filtration through mangroves.

Management of Run-off

At the largest scale it is hoped to reduce catchment run-off of sediments, nutrients and pesticides through the Integrated Catchment Management program. Integrated catchment management is the principal tool of the Queensland Government for reduction of catchment-based pollutant discharge to aquatic systems and the coastal zone. It is coordinated through a Catchment Management Coordinating Committee with broadly based representation.

One objective of the program is to have Integrated Catchment Management implemented in all coastal catchments in the plan by the year 2000. A sub-committee of the Catchment Management Coordinating Committee has the direct responsibility for the downstream effects

of agricultural practices. The Queensland environmental protection legislation also regulates diffuse discharges but agriculture is largely exempted from its provisions.

Management changes in some agricultural industries in recent years have the potential to reduce sediment and nutrient run-off. The most notable example is green cane harvesting and trash blanketing in sugarcane cultivation. With this technique major reductions in soil erosion and phosphorus loss (up to 90%) can be achieved. Sugarcane cultivation areas north of Mackay, except in the Burdekin, have predominantly adopted this practice while south of Mackay usage averages 25%.

In rangeland grazing situations, fencing off streamlines to prevent cattle access and subsequent bank erosion are being trialled. Management systems where grass is maintained above 30% vegetation cover using long-term weather forecasts and subsequent stock number manipulation are also being tested. The critical point above which soil erosion is minimised is 30–40% vegetation cover.

In urban areas development practices which minimise sediment and nutrient run-off in stormwater are being adopted by local government (e.g. the soil erosion and sediment control policy of the Townsville City Council). Minimum vegetation removal or disturbance, the use of sediment traps and vegetated buffers are some of the components of such a policy.

Codes of practice are being developed for many agricultural industries to address environmental problems of the industry. Development is partially in response to the Queensland *Environmental Protection Act 1994* which while not generally including agriculture as an 'Environmentally Relevant Activity' does require a duty of care for all activities that may have environmental consequences. Codes of practice are seen as a voluntary response to this duty of care. Codes of practice have been developed for the cotton industry and the sugar industry in 1998 while a dairy farmers' code is also under development.

Wetlands

Wetlands are vital for the protection of the Great Barrier Reef as they ameliorate the impacts of run-off from catchment uplands. Coastal wetlands disperse and slow the velocity of run-off and this allows entrained sediments, nutrients and toxic compounds to settle out before they enter the Great Barrier Reef lagoon. Littoral vegetation of high integrity protects the coastline, rivers and streams from erosion which can contribute excessive sediment into the marine environment possibly causing deterioration of inshore reefs. Wetlands also play a role as nursery areas for marine species, many of which contribute to the productivity of Great Barrier Reef fisheries.

Wetlands along the Queensland coast adjacent to the World Heritage Area have declined significantly since the 1950s. For example, on the Burdekin floodplain, approximately 80% of ephemeral wetlands have been lost. The degradation of wetlands in much of the Queensland coastal area has the potential to open up acid sulphate soils which can have adverse effects on the marine environment.

Wetlands are an important natural tool for managing non-point source pollutants in catchment management. Preservation of remaining wetlands and rehabilitation of degraded wetlands has been recognised as an important environmental priority. Legislation together with a developing cooperative cross-sectoral approach between governments, industries and landholders are key elements of contemporary wetland management.

Coastal Urban Development

The Great Barrier Reef Marine Park and World Heritage Area have an inter-dependency relationship with the coastal zone. Planning and management for the coastal zone is primarily the role of State and local governments. In its role as lead agency for World Heritage Area matters, the Great Barrier Reef Marine Park Authority is actively involved in a wide range of processes and activities which contribute to the management of potentially detrimental land-based effects adjacent to the World Heritage Area.

Queensland is a highly decentralised state with a pleasant climate very conducive to coastal settlement. There are 21 local governments with boundaries contiguous with the World Heritage Area and more than twice this number lie within the catchment area. Coastal local governments adjacent to the World Heritage Area are amongst the fastest growing population centres in Queensland. They contain all but two of Queensland's major ports, and 37% of hotel/motel rooms and 32% of registered vessels in Queensland.

The impacts of coastal development in or adjacent to the Great Barrier Reef World Heritage Area need to be considered.

Development impacts

Population growth in adjacent urban centres invariably leads to increased pressure for access to Marine Park resources. This becomes a management issue when it results in overuse of certain sections of the Marine Park or where sensitive environments are exposed to excessive human impacts such as damage to corals from anchoring or interference with bird nesting and breeding areas.

Marine Park management through section zoning plans prescribes allowable and permissible uses and provides for a variety of recreation settings both across and between sections. Plans of management provide more detailed information on the management intent for certain areas or specific species such as dugong.

The inappropriate location of new urban centres or the unplanned expansion of existing centres can impact on the management intentions for offshore areas in the Marine Park. Growth in residential nodes often leads to increased demand for marine tourism and recreation infrastructure such as marinas, ferry terminals, safe harbours and jetties. Likewise, the scale, location and character of individual developments, such as large integrated residential and tourist resorts, can pose similar problems for the Marine Park management regime, particularly if they are located adjacent to marine areas with a low-intensity use setting.

In addition to the broader issues of population pressure associated with coastal development there are a number of site specific impacts.

Sediment loss during construction and operational stages of development can reduce Reef water quality. Dumping of dredge spoil from the construction and maintenance of canal and marina developments needs to be managed. Vegetation clearing associated with residential development and recreational uses occurs adjacent to foreshore areas. There are increases in quantities of litter, especially plastics, entering the marine environment and endangering marine species including birds and mammals. Coastal development may be accompanied by loss of visual amenity and changes in the character of coastal areas, often involving a diminution in the cultural value of places as perceived by some users.

Management responses

The development of partnerships with other spheres of government as well as community and sectoral groups is an important management approach for the Great Barrier Reef Marine Park Authority in dealing with outside influences into the Marine Park and World Heritage Area.

To the extent that all or parts of a proposed development occur inside the Marine Park, either along the coastline or around islands, impacts are managed through the assessment of permit applications by the Great Barrier Reef Marine Park Authority. Permits are assessed against criteria prescribed in the *Great Barrier Reef Marine Park Act 1975*. The Queensland Department of Environment and Heritage participates in the assessment process as part of the joint management arrangements between the Commonwealth and the State.

While the Authority's decision-making jurisdiction is generally limited to areas inside the Marine Park, it is able to participate in State and local government assessment processes in its role as a referral agency where development applications trigger 'referral coordination' and where they are adjacent to the World Heritage Area. The commencement in April 1998 of the Queensland *Integrated Planning Act 1997* has introduced major changes to the impact assessment processes of State agencies and local governments. The Great Barrier Reef Marine Park Authority is taking action to ensure its current status is not diminished as a result of these changes.

In addition to its involvement in project specific impact assessment, the Great Barrier Reef Marine Park Authority has also developed partnerships with State and local governments in the preparation of planning frameworks such as Regional Coastal Management Plans and Local Government Planning Schemes. Through these planning instruments State and local governments can increase the level of protection and management afforded to coastal resources which in turn assist in the protection and management of the Marine Park and the values of the World Heritage Area. Other areas of joint concern where the Authority is working closely with local governments include the development of design standards and guidelines for stormwater drainage, wastewater treatment and marinas.

SUMMARY

Land-based activities particularly agricultural, pastoral and urban development pose major threats to maintenance of suitable water quality on the Great Barrier Reef. Management of water quality requires an integrated approach to land and coastal development between governments and industries. Run-off of nutrients from adjacent catchments has been identified as the major water quality issue facing the World Heritage Area.

Implementation of integrated catchment management together with better land management methods and industry codes of practice will result in reduction of nutrient and sediment inputs to the coastal zone. Independent of these improvements in land-use practices, wetlands can play an important part in the management of catchment water quality. Discharge of sewage and other effluents directly in the Marine Park is regulated and coastal cities are increasingly recycling rather than discharging treated effluent.

Coastal urban population growth and large individual developments can lead to increased human pressure on adjacent Marine Park resources. The Great Barrier Reef Marine Park Authority participates in State and local government impact assessment processes for proposed developments adjacent to the World Heritage Area. It is also working with State and local governments in regional planning processes to promote complementary land use and Marine Park management regimes.

OVERVIEW

Shipping is a significant use of the waters of the Great Barrier Reef World Heritage Area. Several major shipping routes intersect at Torres Strait at the northern boundary of the Great Barrier Reef Marine Park. Ships transiting the inner shipping route (between the Queensland coast and outer reefs) carry a wide range of cargoes, including bauxite and alumina, manganese, iron ore, coal, sugar, general container freight and oil.

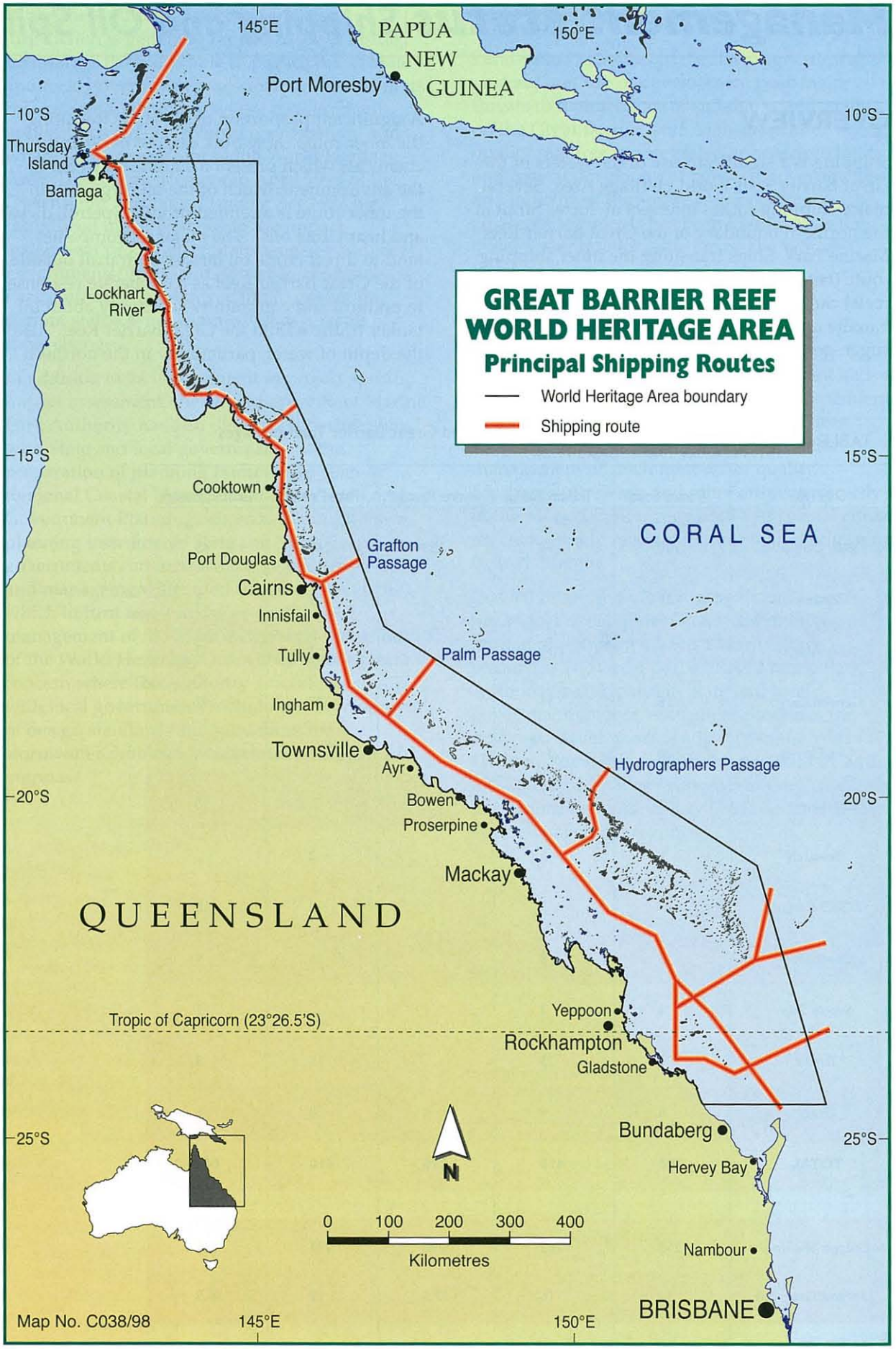
A significant proportion of the ships transiting the inner route carry bulk cargoes of oil and chemicals which present a significant threat to the environment. Much of the oil cargo within the inner route is a refined product (petrol, diesel and heavy fuel oils). The major oil companies tend to direct crude oil tankers to transit outside of the Great Barrier Reef as a deliberate response to political and community sensitivity about oil tanker traffic within the Great Barrier Reef. Also the depth of water, particularly in the northern

TABLE 4 Ship transits through the inner route and Great Barrier Reef passages
(1 November 1997 – 30 April 1998)

Ship Type	Transits South	Transits North	Hydro. Passage#	Palm Passage	Grafton Passage
Bulk Carrier	109	194	289	241	45
Container	124	95		9	5
Gas Tanker	7	11		3	3
General Cargo	18	31	1	82	42
Ore Carrier	28	33			
Passenger	2	1			10
Research	1	2		2	
RORO Cargo*		7		24	15
Specialised	3	8		26	9
Supply Ship	1	2			3
Tanker	8	25		15	3
Other	4	9	6	8	9
TOTAL	**305**	**418**	**296**	**410**	**144**
Longest Ship (m)	255	283	290	291	246
Deepest Draft (m)	13	16	17.5	18	13.5

*Roll-On Roll-Off Cargo

Hydrographers Passage


GREAT BARRIER REEF
WORLD HERITAGE AREA
Principal Shipping Routes
World Heritage Area boundary
Shipping route
PAPUA
NEW
GUINEA
Port Moresby
145°E
150°E
10°S
15°S
20°S
25°S
Thursday
Island
Bamaga
Lockhart
River
Cooktown
Port Douglas
Cairns
Innisfail
Tully
Ingham
Townsville
Ayr
Bowen
Proserpine
Mackay
Yeppoon
Rockhampton
Gladstone
Bundaberg
Hervey Bay
Nambour
BRISBANE
Grafton
Passage
Palm Passage
Hydrographers Passage
CORAL SEA
QUEENSLAND
Tropic of Capricorn (23°26.5'S)
N
0
100
200
300
400
Kilometres
Map No. C038/98

areas of the Reef restricts the draft of vessels transiting the Reef. However, tankers can still carry up to 60 000 tonnes of oil, whilst the larger bulk carriers operating out of Hay Point can carry up to 4000 tonnes of fuel oil.

During the six-month period November 1997 to April 1998, a total of 723 vessels transited the entire length of the inner route. An additional 850 vessels entered the inner route via Hydrographers, Palm and Grafton passages. Approximately 3.3% of all of these shipping movements were oil tankers.

The environmental risks related to shipping within the Great Barrier Reef are operational pollutants and accidental pollutants. The day-to-day operation of a ship produces a number of waste products, including oil, sewage and garbage which can cause problems particularly in areas of high shipping densities (e.g. around ports). Accidental release of fuel or cargo as a result of grounding, collision or structural failure of a vessel has the potential to cause serious environmental damage. The major threat is from oil, either carried as fuel or cargo.

Environmental management of shipping activities is complicated by the international nature of the industry. In most cases management initiatives can only be implemented through multi-lateral actions within the International Maritime Organization. The Australian Maritime Safety Authority represents the Australian Government in this forum.

The framework for the management of shipping activities is determined by a series of international conventions which have been implemented in legislation within Australia, including:

- the United Nations Convention on the Law of the Sea 1982,
- the International Convention for the Prevention of Pollution from Ships 1973 and the 1978 Protocol (MARPOL 73/78),
- International Regulations for Preventing Collisions at Sea 1972, and
- the International Convention for the Safety of Life at Sea 1974.

The Australian Maritime Safety Authority and Queensland Transport have the prime responsibility for the implementation of these conventions within domestic legislation.

CURRENT STATUS

Management of Ship-sourced Pollutants

The International Convention for the Prevention of Pollution from Ships (MARPOL 73/78) regulates the discharge of ship-sourced pollutants. MARPOL has been implemented within domestic legislation through the *Protection of the Sea (Prevention of Pollution from Ships) Act 1983* and the *Great Barrier Reef Marine Park Act 1975*.

MARPOL has five technical annexes. Annexes I and II regulate oil and bulk noxious liquid substances respectively. Annexes III and V regulate harmful substances in packaged forms and garbage. Annex IV regulates sewage but has not been ratified by the member nations of the International Maritime Organization. Further MARPOL annexes are being developed for ballast water management and air pollution regulation. The MARPOL annexes describe the conditions under which operational pollutants can be discharged and design specifications for ships to minimise the need to discharge pollutants

All discharges allowed under MARPOL must occur at set distances from 'nearest land'. In the development of MARPOL the International Maritime Organization recognised the importance of the Great Barrier Reef by defining 'nearest land' as the outer edge of the Reef. This definition effectively prohibits the discharge of all pollutants from ships within the Great Barrier Reef lagoon, except for sewage. Sewage regulations under MARPOL are yet to be ratified and as such sewage is still allowed to be discharged. The Great Barrier Reef Marine Park Act and the Queensland *Transport Operations (Marine Pollution) Act 1975* regulate the discharge of sewage. Despite the high level of regulation, there is still a significant rate of non-compliance with discharge standards.

MARPOL also allows for the declaration of special areas. The Great Barrier Reef was declared the world's first Particularly Sensitive Area under this power. The Particularly Sensitive Area declaration allows for heightened levels of protection to be applied to particular bodies of water, in this case the Great Barrier Reef.

Management of Shipping Activities

The International Maritime Organization has recognised the importance of the Great Barrier Reef and has allowed Australian authorities to implement two vessel management systems which are designed to reduce the risk of accidents: compulsory pilotage, and mandatory vessel reporting and monitoring.

Within the Great Barrier Reef it is compulsory for all vessels over 70 m in length, or carrying bulk oil, chemicals and liquefied gas cargoes to carry a pilot when transiting the inner shipping route north of Cairns and the Hydrographers Passage (off Mackay). The carriage of a pilot reduces the risk of an accident by a factor of 30. Compulsory pilotage does not eliminate the risk of an accident. The MV *Carola* and MV *Peacock* both grounded in the northern Great Barrier Reef whilst carrying pilots.

A further vessel management system known as the Reef Reporting System was implemented in 1996. Under the system all vessels over 50 m in length are required to report their position at specific points along the inner shipping route. The reporting system is integrated with a radar monitoring system at key entrances to the Great Barrier Reef. It acts as a deterrent to ships transiting the inner route without a pilot or intending to evade the mandatory reporting requirements. The Reef Reporting System also allows for information such as weather conditions or shipping congestion to be provided to ships as they transit the Great Barrier Reef. Accurate figures on shipping movements along the inner route of the Great Barrier Reef are now available through the Reef Reporting System.

The Australian Maritime Safety Authority conducts a program of vessel inspections to identify ships that do not meet international safety requirements. The program known as Port State Control aims to deter substandard shipping entering Australian waters through the detention of these vessels. A weakness of the program is that to be detected a vessel must have already transited Australian waters and entered a port. However, there are significant limitations under international law preventing vessels being boarded and inspected whilst still at sea.

Oil Spill Management

The risk of a large oil spill occurring in Australian waters in any one 5-year period has been estimated at 37% (84% in any 20-year period). Further, Torres Strait and the northern section of the inner shipping route have been identified as having highest shipping accident rates for Australia. Contingency planning for such incidents is an ongoing requirement.

Since 1985 there have been in excess of 28 incidents of grounding and 19 collisions, all of which have had the potential to cause a significant oil spill. Only one large oil spill has occurred in the vicinity of the Great Barrier Reef when the oil tanker *Oceanic Grandeur* grounded on an uncharted rock in 1970.

Although there have been no large oil spills within the World Heritage Area, there is an ongoing problem with smaller spills. These can occur through accidental releases of fuel during transfer operations (both on-board transfers and vessel to vessel transfers) and deliberate illegal discharges of waste oil from the merchant shipping and commercial fishing fleets. These regular events, while small in nature (generally less than 10 tonnes) have the potential to cause localised impacts and tie up resources which could be employed elsewhere.

The National Plan to Combat the Pollution of the Sea by Oil is managed by the Australian Maritime Safety Authority and provides an organisational and administrative framework for oil spill response throughout Australia. The National Plan is implemented by the various State contingency plans and through REEFPLAN, a special oil spill contingency plan for the waters of the World Heritage Area. In addition, most port authorities have individual Oil Spill Contingency Plans, or are developing them.

Under REEFPLAN, the Queensland Government, through Queensland Transport, is responsible for initiating oil spill response within the World Heritage Area. The Great Barrier Reef Marine Park Authority provides an environmental and scientific advisory role to Queensland Transport.

Significant resources have been placed along the Queensland coast to respond to oil spills. Most ports have been provided with resources to respond to minor incidents of pollution (up to 10 tonnes of oil). These incidents are the most likely to occur within a port. Larger stockpiles are located in Townsville and Brisbane to respond to larger incidents of between 10–1000 tonnes of oil. For the very large spills of more than 1000 tonnes, resources are available from interstate, in particular the Australian Marine Oil Spill Centre in Geelong, and internationally.

Compulsory pilotage and mandatory vessel reporting reduce the risk of accidents involving large ships traversing the Great Barrier Reef World Heritage Area.

There are several factors limiting oil spill response within the Great Barrier Reef World Heritage Area. The small population centres adjacent to the Reef mean that there is only a limited pool of trained response personnel. In the event of a significant incident, response personnel will be required to be sourced from areas away from Great Barrier Reef. The remoteness of large areas of the Reef, particularly north of Cairns, makes a physical response very difficult. Certainly there will be significant delays in transporting equipment given the limited transport infrastructure in northern Queensland. The response to the MV *Peacock* (which grounded north of Lockhart River) demonstrated the logistical problems associated with remote areas responses.

The use of oil spill dispersants, whilst providing the most credible response option in the northern and offshore areas of the Reef, is significantly limited by the sensitivity of reef and intertidal communities. More importantly the oil most likely to be spilled (heavy fuel oil) is not readily dispersed.

Given these factors and also the technological limitations of oil spill response in general, there needs to be recognition that a significant oil spill is likely to result in impacts to inter-tidal and coastal habitats. The extent of any damage is not easily predicted as it is highly dependent upon local conditions and environments and the specific type of oil. However, significant impacts can be expected on a regional scale in the short to medium term.

SUMMARY

The operation of shipping within the Great Barrier Reef poses serious environmental risk, particularly on the inner shipping route between the Queensland coast and the outer reefs. The management of shipping activities and ship-sourced pollution in the Great Barrier Reef World Heritage Area is complicated by the international nature of the industry. Through concerted diplomatic efforts the level of regulation is the highest afforded any body of water worldwide.

The Australian Maritime Safety Authority and Queensland Transport have the prime responsibility for the environmental management of shipping. Compulsory pilotage on the inner shipping route and a mandatory vessel reporting system have been introduced to reduce the risk of shipping accidents.

There have been no major oil spills in the World Heritage Area although there is an ongoing problem with smaller spills, and numerous vessel groundings and collisions have occurred during the last 20 years. Response to an oil spill is implemented through REEFPLAN, a marine pollution contingency plan for the Great Barrier Reef. The response to pollution incidents is limited by logistical difficulties created by the remoteness of large parts of the Reef and general technological problems.

OVERVIEW

Monitoring is a fundamental component of effective environmental management and conservation. There is a large variety of monitoring programs within the Great Barrier Reef World Heritage Area, and to a large extent this entire report represents a summary of the results of these programs.

Monitoring serves three major purposes. Firstly, it enables managers to determine whether or not specific human activities are having or have had an adverse effect on the environment. Monitoring also enables managers to determine whether their management actions (e.g. reef closures, restrictions of specific types of activity) have had the intended effect. Finally it enables managers to determine the overall state of the system, determine natural levels of variability and to detect unanticipated and subtle long-term or cumulative changes caused by diffuse human activity.

On the Great Barrier Reef, monitoring programs can be divided for convenience into four categories:

- site-specific impact monitoring
- issue-specific monitoring
- long-term background monitoring
- volunteer monitoring.

CURRENT STATUS

Site-specific Impact Monitoring

Site-specific impact monitoring programs include tourist pontoon monitoring, monitoring the impacts of construction and operation of marinas, and monitoring the effects of dredging of port access channels. In this type of program the exact nature, extent and timing of the possible impacts can be defined with some level of precision. This enables a detailed experimental approach to be taken including replicated sampling taken Before and After an impact at both Control and Impact sites (BACI monitoring). Alternatively, compliance monitoring against specific acceptable limits is also an option.

Site-specific monitoring programs are often the most sophisticated in terms of design and analysis against specific hypotheses. The variables which are monitored can be quite numerous and diverse, depending on the nature of the development. Ten principal stages are recognised in the design and implementation of a major impact monitoring program.

Within the Great Barrier Reef Marine Park, all commercial activities require a permit from the Great Barrier Reef Marine Park Authority. During the assessment process for this permit, a decision is made on whether or not predicted

TABLE 5 Ten principal stages in the design and implementation of a site-specific impact monitoring program

Task	Responsibility
1. Set specific testable hypotheses based on predicted–potential impacts identified during assessment.	GBRMPA
2. Set level of effect to be detected and desired power to detect this effect.	GBRMPA, Proponent
3. Conduct pilot study (if needed) to determine optimal sampling and design strategy for monitoring program.	Consultant, GBRMPA
4. Draw up full proposal for monitoring program based on replicated BACI design.	Consultant, GBRMPA
5. Externally review proposal and revise.	GBRMPA, Consultant
6. Conduct monitoring program.	Consultant
7. Write interim and final reports.	Consultant
8. Externally review and revise reports.	GBRMPA, Consultant
9. Review program, decide on management action and need for further monitoring.	GBRMPA, Proponent
10. Disseminate report together with a non-technical summary.	GBRMPA

TABLE 6 Summary of major monitoring programs on the Great Barrier Reef

Program	Target Variables	Agency	Area Covered	Frequency and Longevity	Category
Long-term monitoring of the Great Barrier Reef	• Coral cover • Fish • Crown-of-thorns starfish	• AIMS	>50 reefs over all but far northern area	Once per year Ongoing since 1981	Background
Long-term coral monitoring	• Fate of individual corals	• AIMS • JCU	Selected reefs (~10 reefs)	Once per year Ongoing since 1970s	Background
Water temperature monitoring	• Water temperature	• GBRMPA • CRC Reef	~40 reefs	Continuous recordings Ongoing since 1995	Background
Long-term current monitoring	• Current speed and direction	• AIMS	Two sites: Jewel and Myrmidon Reefs	Continuous recordings Ongoing since 1987	Background
Visitor use monitoring (Environmental Management Charge returns)	• Numbers of visitors • Types of activities	• GBRMPA	All of the reef	Quarterly Ongoing since 1993	Background
Aerial surveillance	• Numbers and types of vessels on the Reef	• QDEH • Coastwatch • GBRMPA	Whole of the reef	Numerous flights per year Ongoing	Background
Dugong monitoring	• Dugong numbers	• JCU • GBRMPA	Transects over whole of the reef	Once every five years Ongoing	Issue-specific
Seabird monitoring	• Numbers of nesting seabirds	• QDEH	>60 selected coral cays and islands over whole of reef	Annual Ongoing since late 1970s	Issue-specific
Turtle monitoring	• Numbers of nesting female turtles	• QDEH	Selected beaches and cays	Annually since late 1970s at principal sites	Issue-specific
Crown-of-thorns starfish fine-scale monitoring	• Crown-of-thorns starfish numbers • Coral cover • Large *Porites*	• GBRMPA • CRC Reef	~24 reefs in Cairns and Central sections	Once per year Ongoing	Issue-specific
Water quality monitoring	• Salinity • Nutrients • Sediment • Chlorophyll	• GBRMPA • AIMS	12 transects from Gladstone to Cape Weymouth	Monthly Ongoing, subject to review	Issue-specific
Flood plume monitoring	• Extent • Nutrient and sediment content	• GBRMPA • AIMS • ANU • SU	Affected areas	Large-scale surveys carried out as required after disturbance events	Issue-specific
Commercial and recreational harvest monitoring	• Fisheries catch and effort statistics	• QFMA • GBRMPA	All of the reef (whole of Queensland)	Quarterly statistics Ongoing since 1988	Issue-specific
Monitoring effects of line fishing	• Fish abundance and recruitment	• GBRMPA • CRC Reef	24 reefs from Swains to Lizard Is	Annually for seven years from 1994 Possibly ongoing	Issue-specific
Effects of trawling monitoring	• Abundance of benthic animals	• CSIRO • GBRMPA	Far Northern Section	1, 2, 4 & 6 years after intensive trawling	Issue-specific
Traditional harvest monitoring	• Numbers of dugongs and turtles caught	• GBRMPA • QDEH	Far Northern Section Aboriginal communities	Annual reports Ongoing	Issue-specific
Seagrass monitoring	• Seagrass distribution and abundance	• DPI	Transects over the whole reef; various study sites for detailed surveys	Irregular surveys Ongoing since 1980s	Issue-specific
Disturbance monitoring	• Coral condition	• GBRMPA • AIMS	Areas affected by cyclones, bleaching	Large-scale surveys carried out as required after disturbance events	Site- and Issue-specific
High-use monitoring	• Coral cover • Coral damage	• QDEH • GBRMPA	~30 sites in Central and Mackay–Capricorn sections	Annual Ongoing since 1995	Site- and Issue-specific
Environmental impact monitoring	• Coral cover • Fish numbers • Coral damage	• GBRMPA • Consultants	All major commercial activities in the Marine Park	Variable Usually ongoing at 1–5 year intervals	Site-specific

KEY: *GBRMPA – Great Barrier Reef Marine Park Authority*
ANU – Australian National University
QFMA – Queensland Fisheries Management Authority
DPI – Queensland Department of Primary Industries
Coastwatch – Branch of Australian Customs Service
AIMS – Australian Institute of Marine Science
SU – University of Sydney
CSIRO – Commonwealth Scientific and Industrial Research Organisation
CRC Reef – Cooperative Research Centre for Ecologically Sustainable Development of the Great Barrier Reef
QDEH – Queensland Department of Environment and Heritage
JCU – James Cook University

impacts are sufficiently significant and likely that a monitoring program is required. If monitoring is required it is included as a condition of the permit.

A significant feature of all major monitoring programs carried out as a condition of an Authority permit is that the monitoring is conducted by an independent consultant who reports directly to the Great Barrier Reef Marine Park Authority. The program is managed and reviewed by the Authority, and the final report must be accepted by the Authority before the report is published. This independence of the monitoring from the proponent reduces any possible conflicts of interest and ensures that uniform, rigorous standards are applied to all programs.

Detailed site-specific monitoring before and after a potential impact will provide essential information on the level and type of adverse changes that may have occurred. However, it does not enable managers to detect problems as they occur, and to instigate management action during the activity in order to minimise further damage.

In cases where the potentially impacting activity occurs over a long time period (weeks to months) a separate 'reactive monitoring program' is required. In such a program, rapid, frequent and more qualitative assessment is made at regular intervals throughout the activity. Daily or weekly reporting on the results of this monitoring enables an on-site environmental site supervisor to detect incipient problems and apply corrective measures before any major damage has occurred. Significant reactive monitoring programs have been carried out during the original construction of the Magnetic Quays marina on Magnetic Island, the extension and deepening of the Townsville Harbour access channel, and the dredging of the boat channel at Port Hinchinbrook near Cardwell.

Issue-specific Monitoring

Issue-specific monitoring programs include monitoring of water quality degradation due to terrestrial run-off, crown-of-thorns starfish monitoring, and monitoring of the impacts of fishing. While the spatial focus of this type of monitoring is often diffuse and variable, the monitoring variables are more focused and easily specified than in site-specific monitoring. Frequently these types of monitoring programs seek to describe the spatial extent and trends in the occurrence of a specific phenomenon, rather than to address a specific hypothesis. A good example of an issue-specific program that has gone beyond the initial description to a more focused examination of specific effects is the Effects of Trawling Program on the Great Barrier Reef.

Long-term Background Monitoring

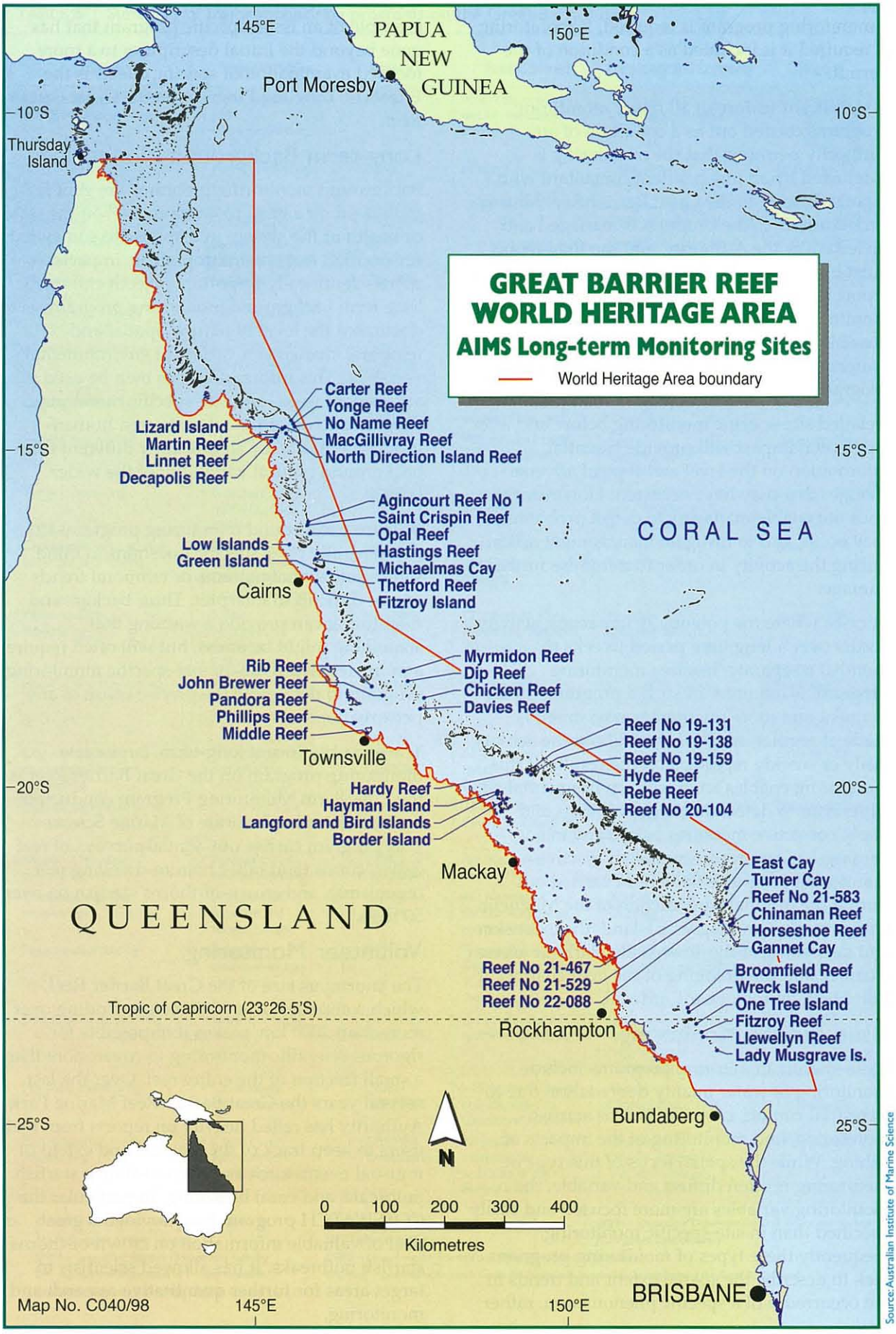
Background monitoring programs are generally motivated by a need to 'keep an eye' on the state or health of the system in response to somewhat unspecified fears of anthropogenic impacts. A more scientifically important objective of many long-term background monitoring programs is to document the level of natural spatial and temporal change in a variety of environmental variables. This information can then be used in subsequent issue- and site-specific monitoring programs to determine if suspected human-induced impacts are significantly different from background natural variability of the wider system.

Because background monitoring programs do not generally have specific questions in mind, significant spatial patterns or temporal trends can be difficult to interpret. Thus, background monitoring can provide a warning that something might be amiss, but will often require a more detailed issue- or site-specific monitoring program to determine the precise cause of any perturbation.

The most significant long-term, large-scale monitoring program on the Great Barrier Reef is the Long-term Monitoring Program conducted by the Australian Institute of Marine Science. This program carries out annual surveys of reef fishes, corals (and other bottom-dwelling reef organisms), and crown-of-thorns starfish on over 50 reefs.

Volunteer Monitoring

The enormous size of the Great Barrier Reef, which comprises over 2800 reefs extending over more than 2000 km, makes it impossible for rigorous scientific monitoring to cover more than a small fraction of the entire reef. Over the last several years the Great Barrier Reef Marine Park Authority has relied heavily on reports from reef users to keep track of the location and extent of unusual events such as crown-of-thorns starfish outbreaks and coral bleaching. In particular the COTSWATCH program has provided a great deal of valuable information on crown-of-thorns starfish outbreaks. It has allowed scientists to target areas for further quantitative research and monitoring.


GREAT BARRIER REEF
WORLD HERITAGE AREA
AIMS Long-term Monitoring Sites
World Heritage Area boundary
145°E
150°E
PAPUA
NEW
GUINEA
Port Moresby
10°S
Thursday
Island
15°S
20°S
25°S
Carter Reef
Yonge Reef
No Name Reef
MacGillivray Reef
North Direction Island Reef
Lizard Island
Martin Reef
Linnet Reef
Decapolis Reef
Agincourt Reef No 1
Saint Crispin Reef
Opal Reef
Hastings Reef
Michaelmas Cay
Thetford Reef
Fitzroy Island
Low Islands
Green Island
Cairns
CORAL SEA
Myrmidon Reef
Dip Reef
Chicken Reef
Davies Reef
Rib Reef
John Brewer Reef
Pandora Reef
Phillips Reef
Middle Reef
Townsville
Reef No 19-131
Reef No 19-138
Reef No 19-159
Hyde Reef
Rebe Reef
Reef No 20-104
Hardy Reef
Hayman Island
Langford and Bird Islands
Border Island
Mackay
East Cay
Turner Cay
Reef No 21-583
Chinaman Reef
Horseshoe Reef
Gannet Cay
QUEENSLAND
Reef No 21-467
Reef No 21-529
Reef No 22-088
Broomfield Reef
Wreck Island
One Tree Island
Fitzroy Reef
Llewellyn Reef
Lady Musgrave Is.
Tropic of Capricorn (23°26.5'S)
Rockhampton
Bundaberg
N
0 100 200 300 400
Kilometres
BRISBANE
Map No. C040/98
Source: Australian Institute of Marine Science

More recently, trial volunteer monitoring programs such as Eye on the Reef and Reef Watch have been instigated in the Cairns and Port Douglas areas. These programs aim to determine the extent to which volunteers from the tourist industry can play a role in reporting on general reef health and unusual events or changes in the areas around specific tourist sites. Both programs show promise, and it is anticipated that the Eye on the Reef program will be continued and expanded over the next several years. Volunteer monitoring has also provided Australian input to the Global Coral Reef Monitoring Network and international Reef Check program, in which hundreds of sites are evaluated over a number of countries worldwide. Another volunteer monitoring group which has instigated coral surveys is the Order of Underwater Coral Heroes in the Whitsunday area.

While there is substantial and largely untapped potential for volunteers within the community and reef-based industries to contribute to our awareness of events and changes on the reef, a number of issues need to be addressed in order to ensure that the information collected under such schemes is of value to managers and other reef users. Further work is necessary on designing programs which can be readily implemented by non-scientific personnel with only limited training, and which are able to produce consistent and reliable and useful information. The coordination and standardisation of volunteer monitoring efforts is an area on which the Great Barrier Reef Marine Park Authority will focus over the next few years.

SUMMARY

Monitoring is a fundamental management tool to document environmental impacts, both natural and anthropogenic, and assess the effectiveness of management actions. Long-term background monitoring provides information on the overall state of the system and any long-term trends. Current background monitoring programs target water quality, corals and visitor use.

All major commercial activities in the Marine Park are subject to environmental impact monitoring. This site-specific impact monitoring is conducted by independent consultants and managed by the Great Barrier Reef Marine Park Authority. Reactive monitoring programs are established when a potentially impacting activity occurs over a long period of time and ensures any indications of adverse impacts are detected as soon as possible.

Issue-specific monitoring provides information on particular phenomena, and programs are coordinated by a range of organisations. Current programs include monitoring dugong numbers, effects of fishing and flood plumes. Volunteers can provide a Reef-wide monitoring effort and have provided useful information on general reef health and unusual events such as coral bleaching and crown-of-thorns starfish numbers.

This researcher is videoing the coral and other marine life to help monitor the state of the Reef.

Glossary

benthos/benthic:
Associated with the bottom of the sea.

biodiversity:
The variety of all life forms: the different plants, animals and micro-organisms, the genes they contain and the ecosystems they form. It is a concept that emphasises the inter-relatedness of the biological world. It is often considered at three levels: genetic diversity, species diversity and ecosystem diversity.

biomass:
As measured by ecologists, the mass of all organic matter in the ecosystem.

bycatch:
Species taken incidentally in a fishery where other species are the target. Bycatch species are often discarded.

bycatch reduction device:
Any modification to a prawn trawl designed to reduce the capture of bycatch. Includes fish eyes and turtle excluder devices.

catch per unit effort:
Catch taken for a given amount of fishing effort. It is expressed as a ratio.

cod end:
The last section of net in a prawn trawl net, where the catch is collected and held during the trawling operation.

CRC Reef Research Centre:
Cooperative Research Centre for Ecologically Sustainable Development of the Great Barrier Reef.

ecologically sustainable development:
Development which meets the needs of the present without compromising the ability of future generations to meet their needs. Development which is compatible with the continuing functioning of essential ecological processes.

endemic/endemism:
'Native' species confined to a given region (e.g. a species endemic to the Great Barrier Reef is not found anywhere else).

eutrophication:
Increase in the nutrient status of a water body, and consequently the rapid growth of plants, both natural and as a result of human activity.

fish eye:
A hole made deliberately in the net of a prawn trawl net to allow fish to escape. A fish eye is one kind of bycatch reduction device.

monitoring:
Routine counting, testing or measuring of environmental factors or organisms to determine their status or condition.

pelagic:
Associated with the surface or middle depths (as opposed to the bottom) of a body of water.

precautionary principle:
A principle of ecologically sustainable development providing that, where there are threats of serious or irreversible damage, the lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation.

preservation zone:
The highest level of protection afforded to an area under Great Barrier Reef Marine Park zoning plans. Public access is prohibited to areas in preservation zones.

primary treatment:
The first step in sewage treatment removes large solid objects by screens (filters) and sediment and organic matter in settling chambers (see secondary and tertiary treatment).

run-off:
Water discharged from the land that enters the sea either directly, or indirectly after passing through streams and rivers.

secondary treatment:
After primary treatment, removal of biodegradable organic matter from sewage using bacteria and other micro-organisms, inactivated sludge or trickle filters. Also removes some of the phosphorus (30%) and nitrate (50%) (see primary and tertiary treatment).

standard error:
An indication of the degree of uncertainty associated with measurements in scientific studies.

suspended solids:
Any solid substance present in water in an undissolved state, usually contributing directly to turbidity.

tertiary treatment:
Removal of nitrates, phosphates, chlorinated compounds, salts, acids, metals and toxic organics after secondary treatment (see primary and secondary treatment).

turbidity:
The cloudy water conditions caused by suspended solids.

turtle excluder device:
An inclined grid or net panel that prevents large animals (particularly turtles) from entering the cod end of a prawn trawl net. A turtle excluder device is one kind of bycatch reduction device.

wetlands:
Land areas along fresh and salt water (coastal wetlands, such as salt marshes, tidal basins and mangrove swamps) that are flooded all or part of the time.

zoning plan:
A plan that divides an area of the Great Barrier Reef Marine Park into zones, and that describes the purposes for which each zone may be used or entered. Activities which are covered by the zoning plans include bait netting and gathering, crabbing, oyster gathering, diving, boating, photography, line fishing, spear fishing, trawling, research, tourism and education facilities and programs and traditional hunting, fishing and gathering.

Bibliography

The sources of written information used to produce this report are listed below. For ease of reference, these publications and other papers are grouped according to the sections of the report itself.

Three books were used extensively in the production of the report:

Lucas, P. H. C., Webb, T., Valentine, P. S. & Marsh, H. 1997, *The Outstanding Universal Value of the Great Barrier Reef World Heritage Area*, Great Barrier Reef Marine Park Authority, Townsville.

The Great Barrier Reef: Science, Use and Management: proceedings of a national conference held at James Cook University of North Queensland, Townsville, Queensland, Australia, 25–29 November 1996, 1997, vols 1 & 2, Great Barrier Reef Marine Park Authority, Townsville.

Wachenfeld, D. R., Oliver, J. K. & Davis, K. (eds) 1997, *State of the Great Barrier Reef World Heritage Area Workshop: proceedings of a technical workshop held in Townsville, Queensland, Australia, 27–29 November 1995*, Workshop Series no. 23, Great Barrier Reef Marine Park Authority, Townsville.

Throughout this bibliography the last two references are referred to as *The Great Barrier Reef: Science, Use and Management* and *State of the Great Barrier Reef World Heritage Area Workshop* respectively.

INTRODUCTION

Burrage, D., Steinberg, C., Bode, L. & Black, K. 1997, 'Long-term current observations in the Great Barrier Reef', in *State of the Great Barrier Reef World Heritage Area Workshop*, 21–45.

Lough, J. M. 1997, 'Recent climate variation on the Great Barrier Reef', in *State of the Great Barrier Reef World Heritage Area Workshop*, 7–20.

Wolanski, E. 1994, *Physical Oceanographic Processes of the Great Barrier Reef*, CRC Marine Science Series, CRC Press, Boca Raton.

ENVIRONMENTAL STATUS

Water Quality

Australian Bureau of Statistics 1997, *Queensland Year Book 1997*, Australian Bureau of Statistics, Brisbane.

Bell, P. R. F. & Elmetri, I. 1995, 'Ecological indicators of large-scale eutrophication in the Great Barrier Reef lagoon', *Ambio*, 24(4), 208–15.

Brodie, J. 1997, 'The water quality status of the Great Barrier Reef World Heritage Area', in *State of the Great Barrier Reef World Heritage Area Workshop*, 69–96.

Brodie, J. & Furnas, M. 1996, 'Cyclones, river flood plumes and natural water quality extremes in the central Great Barrier Reef', in *Downstream Effects of Land Use*, eds H. M. Hunter, A. G. Eyles & G. E. Rayment, Department of Natural Resources, Brisbane, 367–74.

Brodie, J. E., Furnas, M. J., Steven, A. D. L., Trott, L. A., Pantus, L. A. & Wright, M. 1997, 'Monitoring chlorophyll in the Great Barrier Reef lagoon: trends and variability', in *Proceedings of the 8th International Coral Reef Symposium, Panama, June 24–29 1996*, vol. 1, eds H. A. Lessios & I. G. Macintyre, Smithsonian Tropical Research Institute, Balboa, 797–802.

Bureau of Immigration and Population Research 1993, *Migration Population and Growth and Regional Development in Queensland*, Australian Government Publishing Service, Canberra.

Furnas, M. J. & Brodie, J. 1996, 'Current status of nutrient levels and other water quality parameters in the Great Barrier Reef', in *Downstream Effects of Land Use*, eds H. M. Hunter, A. G. Eyles & G. E. Rayment, Department of Natural Resources, Brisbane, 9–21.

Furnas, M. J. & Mitchell, A. W. 1997, 'Biological oceanography of the Great Barrier Reef', in *The Great Barrier Reef: Science, Use and Management*, vol. 1, 75–87.

Furnas, M., Mitchell, A. W. & Skuza, M. 1995, *Nitrogen and Phosphorus Budgets for the Central Great Barrier Reef Shelf*, Research Publication no. 36, Great Barrier Reef Marine Park Authority, Townsville.

Furnas, M., Mitchell, A. & Skuza, M. 1997, 'River inputs of nutrients and sediment to the Great Barrier Reef', in *State of the Great Barrier Reef World Heritage Area Workshop*, 46–68.

Graetz, R. D., Wilson, M. A. & Campbell, S. K. 1995, *Landcover Disturbance over the Australian Continent: A Contemporary Assessment*, Biodiversity Series Paper no. 7, Department of the Environment, Sport and Territories, Canberra.

Johnson, A. K. L., Ebert, S. P. & Murray, A. E. 1998, 'Spatial and temporal distribution of wetland and riparian zones and opportunities for their management in catchments adjacent to the Great Barrier Reef Marine Park', in *Protection of Wetlands Adjacent to the Great Barrier Reef: proceedings of a workshop held in Babinda, Queensland, Australia, 25–26 September 1997*, eds D. Haynes, D. Kellaway & K. Davis, Great Barrier Reef Marine Park Authority, Townsville, (Workshop Series no. 24), 82–101.

Johnson, D., Larcombe, P., Carter, B., Orpin, A., Ridd, P. & Woolfe, K. 1997, 'Geoscience issues on the Great Barrier Reef: time scales for reef and shelf processes', in *The Great Barrier Reef: Science, Use and Management*, vol. 1, 225–41.

Mitchell, A. W. & Furnas, M. J. 1997, 'Terrestrial inputs of nutrients and suspended sediments to the Great Barrier Reef lagoon', in *The Great Barrier Reef: Science, Use and Management*, vol. 1, 59–71.

Mitchell, A. W., Reghenzani, J. R., Hunter, H. M. & Bramley, R. G. V. 1996, 'Water quality and nutrient fluxes from river systems draining to the Great Barrier Reef Marine Park', in *Downstream Effects of Land Use*, eds H. M. Hunter, A. G. Eyles & G. E. Rayment, Department of Natural Resources, Brisbane, 23–33.

Moss, A. J., Rayment, G. E., Reilly, N. & Best, E. K. 1992, *A Preliminary Assessment of Sediment and Nutrient Exports from Queensland Coastal Catchments*, Department of Environment and Heritage and Department of Primary Industries, Brisbane.

Preen, A. R., Lee Long, W. J. & Coles, R. G. 1995, 'Flood and cyclone related loss, and partial recovery, of more than 1000 km^2 of seagrass in Hervey Bay, Queensland, Australia', *Aquatic Botany*, 52, 3–17.

Pulsford, J. S. 1996, *Historical nutrient usage in coastal Queensland river catchments adjacent to the Great Barrier Reef Marine Park*, Research Publication no. 40, Great Barrier Reef Marine Park Authority, Townsville.

Rayment, G. E. & Neil, D. T. 1997, 'Sources of material in river discharge', in *The Great Barrier Reef: Science, Use and Management*, vol. 1, 42–58.

Mangroves

Beumer, J., Carseldine, L. & Zeller, B. (eds) 1997, *Declared Fish Habitat Areas in Queensland*, Queensland Department of Primary Industries, Brisbane.

Couchman, D., Mayer, D. & Beumer, J. (comps) 1996, *Departmental Procedures for Permit Applications Assessment and Approvals for Marine Plants*, Fish Habitat Management Operational Policy FHMOP 001, Queensland Department of Primary Industries, Brisbane.

Duke, N. C. 1997, 'Mangroves in the Great Barrier Reef World Heritage Area: current status, long-term trends, management implications and research', in *State of the Great Barrier Reef World Heritage Area Workshop*, 288–99.

Island Plants

Batianoff, G. N. & Dillewaard, H. A. 1997, 'Floristic analysis of the Great Barrier Reef continental islands, Queensland', in *State of the Great Barrier Reef World Heritage Area Workshop*, 300–322.

Olds, J. A., Elder, R. J., Charles, R. M., Platten, J. R. & Bell, K. L. 1997, '*Pulvinaria urbicola* Cockerell on *Pisonia grandis* at Tryon Island'(abstract only), in *The Great Barrier Reef: Science, Use and Management*, vol. 2, 197.

Seagrasses

Great Barrier Reef Marine Park Authority 1992, *Basis for Zoning: The Great Barrier Reef Marine Park Cairns Section and the Cairns Marine Park*, Great Barrier Reef Marine Park Authority, Townsville.

Great Barrier Reef Marine Park Authority 1997, *Marine Parks of Cape York: Proposed Zoning and Management for the Far Northern Section of the Great Barrier Reef Marine Park and Zoning of the Proposed Cape York Marine Park*, Great Barrier Reef Marine Park Authority, Townsville.

Lee Long, W. J. & Coles, R. G. 1997, 'Impacts on and responses of seagrasses in the Great Barrier Reef: issues for management', in *The Great Barrier Reef: Science, Use and Management*, vol. 1, 101–6.

Lee Long, W. J. & Coles, R. G. 1997, 'Status of seagrasses in the Great Barrier Reef region', in *State of the Great Barrier Reef World Heritage Area Workshop*, 185–93.

Macroalgae

Ayling, A. 1997, 'The biological status of fringing reefs in the Great Barrier Reef World Heritage Area', in *State of the Great Barrier Reef World Heritage Area Workshop*, 109–13.

Bell, P. R. F. & Elmetri, I. 1995, 'Ecological indicators of large-scale eutrophication in the Great Barrier Reef lagoon', *Ambio*, 24(4), 208–15.

McCook, L. & Price, I. R. 1997, 'Macroalgal distributions on the Great Barrier Reef: a review of patterns and causes', in *The Great Barrier Reef: Science, Use and Management*, vol. 2, 37–46.

McCook, L. & Price, I. R. 1997, 'The state of the algae of the Great Barrier Reef: what do we know?', in *State of the Great Barrier Reef World Heritage Area Workshop*, 194–204.

Corals

Ayling, A. 1997, 'The biological status of fringing reefs in the Great Barrier Reef World Heritage Area', in *State of the Great Barrier Reef World Heritage Area Workshop*, 109–13.

Bell, P. R. F. & Elmetri, I. 1995, 'Ecological indicators of large-scale eutrophication in the Great Barrier Reef lagoon', *Ambio*, 24(4), 208–15.

Brodie, J. 1997, 'The water quality status of the Great Barrier Reef World Heritage Area', in *State of the Great Barrier Reef World Heritage Area Workshop*, 69–96.

Connell, J. H., Hughes, T. P. & Wallace, C. C. 1997, 'Long-term dynamics of reef crest corals on Heron Island: 1960s to 1990s', in *State of the Great Barrier Reef World Heritage Area Workshop*, 114–23.

Dinesen, Z. & Oliver, J. 1997, 'Tourism impacts', in *State of the Great Barrier Reef World Heritage Area Workshop*, 414–27.

Done, T. J. 1982, 'Patterns in the distribution of coral communities across the central Great Barrier Reef', *Coral Reefs*, 1(2), 95–107.

Done, T. J., DeVantier, L. M., Turak, E., McCook, L. & Fabricius, K. 1997, 'Decadal changes in community structure in Great Barrier Reef coral reefs', in *State of the Great Barrier Reef World Heritage Area Workshop*, 97–108.

Lough, J. M. & Barnes, D. J. 1997, 'Centuries-long records of coral growth on the Great Barrier Reef', in *State of the Great Barrier Reef World Heritage Area Workshop*, 149–57.

Moss, A. J., Rayment, G. E., Reilly, N. & Best, E. K. 1992, *A Preliminary Assessment of Sediment and Nutrient Exports from Queensland Coastal Catchments*, Queensland Department of Environment and Heritage, Brisbane.

Osborne, K., Ninio, R. & Sweatman, H. 1997, 'The current status of sessile benthic organisms on the Great Barrier Reef', in *State of the Great Barrier Reef World Heritage Area Workshop*, 124–33.

Puotinen, M. L., Done, T. J. & Skelly, W. C. 1997, *An Atlas of Tropical Cyclones in the Great Barrier Reef Region, 1969–1997*, CRC Reef Research Technical Report no. 19, CRC Reef Research Centre, Townsville.

Sweatman, H., Ninio, R., Osborne, K. & Ryan, D. 1997, 'Corals and sessile benthos', in *Long-term Monitoring of the Great Barrier Reef*, ed. H. Sweatman, Australian Institute of Marine Science, Townsville, (Status Report no. 2), 99–126.

Veron, J. E. N. 1995, *Corals in Space and Time: The Biogeography and Evolution of the Scleractinia*, UNSW Press, Sydney.

Wachenfeld, D. R. 1997, 'Long-term trends in the status of coral reef-flat benthos: the use of historical photographs', in *State of the Great Barrier Reef World Heritage Area Workshop*, 134–48.

Crown-of-thorns Starfish

Engelhardt, U. 1997, 'COTS Comms', *Reef Research*, 7(2), 12–16.

Engelhardt, U. & Lassig, B. R. 1997, 'A review of the possible causes and consequences of outbreaks of the crown-of-thorns starfish (*Acanthaster planci*) on the Great Barrier Reef: an Australian perspective', in *The Great Barrier Reef: Science, Use and Management*, vol. 1, 243–59.

Engelhardt, U., Miller, I., Lassig, B. R., Sweatman, H. P. A. & Bass, D. 1997, 'Crown-of-thorns starfish (*Acanthaster planci*) populations in the Great Barrier Reef World Heritage Area: status report 1995–96', in *State of the Great Barrier Reef World Heritage Area Workshop*, 158–84.

Miller, I., Bass, D. & Sweatman, H. 1997, 'Broadscale surveys', in *Long-term Monitoring of the Great Barrier Reef*, ed. H. Sweatman, Australian Institute of Marine Science, Townsville, (Status Report no. 2), 9–27.

Williams, D. McB. 1997, 'Long-term monitoring of reef fishes: effects of crown-of-thorns starfish', in *State of the Great Barrier Reef World Heritage Area Workshop*, 228–30.

Fishes

Ayling, A. 1997, 'Long-term trends in reef fish abundance in the Great Barrier Reef World Heritage Area', in *State of the Great Barrier Reef World Heritage Area Workshop*, 223–27.

Ayling, A. M. & Ayling, A. L. 1998, Bramble Reef Replenishment Area: Third Post-opening Survey, Unpublished final report by Sea Research for the Great Barrier Reef Marine Park Authority.

Elmer, M. 1997, 'Reef fish fisheries in the Great Barrier Reef World Heritage Area', in *State of the Great Barrier Reef World Heritage Area Workshop*, 346–51.

Gwynne, H. L. 1997, 'Status of the Great Barrier Reef World Heritage Area: estuarine and inshore fisheries', in *State of the Great Barrier Reef World Heritage Area Workshop*, 363–65.

Higgs, J. 1997, 'Fishing club activities on the Great Barrier Reef', in *State of the Great Barrier Reef World Heritage Area Workshop*, 335–45.

Mapstone, B. D., Davies, C. R. & Robertson, J. W. 1997, 'The effects of line fishing on the Great Barrier Reef: available evidence and future directions', in *The Great Barrier Reef: Science, Use and Management*, vol. 1, 178–92.

McPherson, G. 1997, 'Pelagic fishes', in *State of the Great Barrier Reef World Heritage Area Workshop*, 366–74.

'The live reef fish debate: what are the facts?' 1998, *Queensland Fisheries News*, 2, 1, 4–5.

Russell, M. 1997, 'Management implications learnt from closing and re-opening a coral reef to fishing', *Reef Research*, 7(2), 10–11.

Sweatman, H., Thompson, A. & Cheal, A. 1997, 'The status of reef fishes on the Great Barrier Reef', in *State of the Great Barrier Reef World Heritage Area Workshop*, 205–22.

Sweatman, H., Thompson, A., Cheal, A. & Ryan, D. 1997b, 'Fishes', in *Long-term Monitoring of the Great Barrier Reef*, ed. H. Sweatman, Australian Institute of Marine Science, Townsville, (Status Report no. 2), 63–97.

Turnbull, C. T. & Samoilys, M. A. 1997, *Effectiveness of Spawning Closures in Managing the Line Fishery on the Great Barrier Reef*, Queensland Fisheries Management Authority, Fortitude Valley.

Williams, L. E. (ed.) 1997, *Queensland's Fisheries Resources: Current Condition & Recent Trends 1988–1995*, Department of Primary Industries, Brisbane.

Birds

Heatwole, H., O'Neill, P., Jones, M. & Preker, M. 1996, *Long-term population trends of seabirds on the Swain Reefs, Great Barrier Reef*, CRC Reef Research Technical Report no. 12, CRC Reef Research Centre, Townsville.

Hulsman, K., O'Neill, P. & Stokes, T. 1997, 'Current status and trends of seabirds on the Great Barrier Reef', in *State of the Great Barrier Reef World Heritage Area Workshop*, 259–82.

Hulsman, K., O'Neill, P., Stokes, T. & Warnett, M. 1997, 'Threats, status, trends and management of seabirds on the Great Barrier Reef', in *The Great Barrier Reef: Science, Use and Management*, vol. 1, 164–77.

Stokes, T., Hulsman, K., Ogilvie, P. & O'Neill, P. 1996, 'Management of human visitation to seabird islands of the Great Barrier Reef Marine Park Region', *Corella*, 20(1), 1–13.

WBM Oceanics Australia & Claridge, G. 1997, *Guidelines for Managing Visitation to Seabird Breeding Islands*, Great Barrier Reef Marine Park Authority, Townsville.

Reptiles

Baillie, J. & Groombridge, B. (eds) 1996, *1996 IUCN Red List of Threatened Animals*, IUCN, Gland.

Convention on International Trade in Endangered Species of Wild Fauna and Flora 1973, Washington.

Limpus, C. J. 1997, 'Marine turtles of the Great Barrier Reef World Heritage Area', in *State of the Great Barrier Reef World Heritage Area Workshop*, 256–58.

Marsh, H., Corkeron, P. J., Limpus, C. J., Shaughnessy, P. D. & Ward, T. M. 1995, 'The reptiles and mammals in Australian seas: their status and management', in *The State of the Marine Environment Report for Australia: Technical Annex 1: The Marine Environment*, eds L. P. Zann & P. Kailola, Great Barrier Reef Marine Park Authority, Townsville, 151–66.

Marsh, H., Arnold, P. W., Limpus, C. J., Birtles, A., Breen, B., Robins, J. & Williams, R. 1997, 'Endangered and charismatic megafauna', in *The Great Barrier Reef: Science, Use and Management*, vol. 1, 124–38.

Miller, J. D. & Bell, I. P. 1997, 'Crocodiles in the Great Barrier Reef World Heritage Area', in *State of the Great Barrier Reef World Heritage Area Workshop*, 248–55.

Queensland Fisheries Management Authority 1998, *Queensland Trawl Fishery: Proposed Management Arrangements (East Coast – Moreton Bay) 1998–2005*, Queensland Fisheries Management Authority, Brisbane.

State of the Environment Advisory Council 1996, *Australia: State of the Environment 1996*, CSIRO Publishing, Collingwood.

The Trawl Fishery Management Advisory Committee 1996, *Queensland Trawl Fishery*, Discussion Paper no. 5, Queensland Fisheries Management Authority, Fortitude Valley.

Marine Mammals

Arnold, P. W. 1998, 'Sightings of dwarf minke whales (*Balaenoptera acutorostrata*) on the northern Great Barrier Reef, Australia', *Reports of the International Whaling Commission (SC/48/SH 18)*, 47, 419–24.

Arnold, P. W. & Birtles, R. A. 1998, Towards sustainable management of the developing dwarf minke whale tourism industry in northern Queensland, Report to the Scientific Committee of the International Whaling Commission (SC/50/WW1).

Baillie, J. & Groombridge, B. (eds) 1996, *1996 IUCN Red List of Threatened Animals*, IUCN, Gland.

Bannister, J. L., Kemper, C. M. & Warneke, R. M. 1996, *The Action Plan for Australian Cetaceans*, Australian Nature Conservation Agency, Canberra.

Bryden, M. M., Brown, M. R., Field, M. S., Clarke, E. D. & Butterworth, D. S. 1996, Survey of humpback whales (*Megaptera novaeangliae*) off eastern Australia, 1996, Report to the Australian Nature Conservation Agency. 77 pages.

Convention on International Trade in Endangered Species of Wild Fauna and Flora 1973, Washington.

Corkeron, P. 1997, 'The status of cetaceans in the Great Barrier Reef Marine Park', in *State of the Great Barrier Reef World Heritage Area Workshop*, 283–87.

Corkeron, P. J., Morissette, N. M., Porter, L. & Marsh, H. in press, 'Distribution and status of hump-back dolphins, *Sousa chinensis*, in Australian waters', *Asian Marine Biology*.

Marsh, H. & Corkeron, P. 1997, 'The status of the dugong in the Great Barrier Reef Marine Park', in *State of the Great Barrier Reef World Heritage Area Workshop*, 231–47.

Marsh, H., Arnold, P. W., Limpus, C. J., Birtles, A., Breen, B., Robins, J. & Williams, R. 1997, 'Endangered and charismatic megafauna', in *The Great Barrier Reef: Science, Use and Management*, vol. 1, 124–38.

Queensland Department of Primary Industries 1998, *The Queensland Shark Control Program: Report of the Committee of Review*, Queensland Department of Primary Industries, Brisbane.

Inter-reefal and Lagoonal Benthos

Gribble, N. A. 1997, 'Penaeid prawn stocks', in *State of the Great Barrier Reef World Heritage Area Workshop*, 402–13.

Pitcher, C. R. 1997, 'Status of inter-reefal benthos in the Great Barrier Reef World Heritage Area', in *State of the Great Barrier Reef World Heritage Area Workshop*, 323–34.

Pitcher, C. R., Burridge, C. Y., Wassenberg, T. J. & Poiner, I. R. 1997, 'The effects of prawn trawl fisheries on Great Barrier Reef seabed habitats', in *The Great Barrier Reef: Science, Use and Management*, vol. 1, 107–23.

Poiner, I., Blaber, S., Brewer, D., Burridge, C., Caesar, D., Connell, M., Dennis, D., Dews, G., Ellis, N., Farmer, M., Glaister, J., Gribble, N., Hill, B., O'Connor, R., Pitcher, R., Salini, J., Taranto, T., Thomas, M., Toscas, P., Wang, Y., Veronise, S. & Wassenberg, T. 1997, Final Report on Effects of Prawn Trawling on Far Northern Section of Great Barrier Reef, Draft final report to Great Barrier Reef Marine Park Authority and Fisheries Research and Development Corporation on 1991–96 (Years 1–5) research. CSIRO Division of Fisheries and Queensland Department of Primary Industries.

Williams, L. E. (ed.) 1997, *Queensland's Fisheries Resources: Current Condition & Recent Trends 1988–1995*, Department of Primary Industries, Brisbane.

MANAGEMENT STATUS

Marine Park Management

Great Barrier Reef Marine Park Authority 1994, *The Great Barrier Reef, Keeping it Great: A 25 Year Strategic Plan for the Great Barrier Reef World Heritage Area 1994–2019*, Great Barrier Reef Marine Park Authority, Townsville.

IUCN, Commission on National Parks and Protected Areas with the assistance of the World Conservation Monitoring Centre, 1994 *Guidelines for Protected Area Management Categories*, IUCN, Gland, Switzerland.

Fisheries

Brown, I. W. 1997, 'Crustacean resources (other than prawns) in the Great Barrier Reef World Heritage Area', in *State of the Great Barrier Reef World Heritage Area Workshop*, 375–94.

Healy, T. 1997, 'Queensland east coast trawl fisheries', in *State of the Great Barrier Reef World Heritage Area Workshop*, 352–62.

The Reef Fish Management Advisory Committee 1996, *Queensland Tropical Coral Reef Fish Species*, Discussion Paper no. 2, Queensland Fisheries Management Authority, Fortitude Valley.

Robertson, J. 1997, 'The management of fisheries in the Great Barrier Reef Marine Park', in *State of the Great Barrier Reef World Heritage Area Workshop*, 395–401.

Tanzer, J. M., Elmer, M. A. & Healy, T. 1997, 'Fisheries management in the Great Barrier Reef region', in *The Great Barrier Reef: Science, Use and Management*, vol. 1, 298–306.

The Trawl Fishery Management Advisory Committee 1996, *Queensland Trawl Fishery*, Discussion Paper no. 5, Queensland Fisheries Management Authority, Fortitude Valley.

Tourism

Claringbould, R., Deakin, J. & Foster, P. 1984, *Data Review of Reef Related Tourism 1946–1980*, Research Publication, Great Barrier Reef Marine Park Authority, Townsville.

Dinesen, Z. D. 1995, 'New approaches to managing tourism impacts in the Great Barrier Reef Marine Park', in *Recent advances in marine science and technology '94*, eds O. Bellwood, H. Choat & N. Saxena, Pacon International and James Cook University, Townsville, 505–10.

Great Barrier Reef Marine Park Authority 1998, *Cairns Area Plan of Management*, Great Barrier Reef Marine Park Authority, Townsville.

Great Barrier Reef Marine Park Authority 1998, *Whitsundays Plan of Management*, Great Barrier Reef Marine Park Authority, Townsville.

Honchin, C. 1996, Planning for latent capacity: a case study in managing increasing tourism use in the Great Barrier Reef Marine Park, Paper presented to Coast to Coast Conference '96 Adelaide Australia.

Moscardo, G. 1996, Understanding patterns of travel in the Great Barrier Reef Region: implications for management of coastal and marine tourism, Paper presented at the 2nd Congress on Marine Tourism in Honolulu July 1996.

Moscardo, G., Pearce, P., Woods, B., Murphy, L. & Ross, G. 1997, 'Quality reef tourism: building a web of strategic knowledge', in *State of the Great Barrier Reef World Heritage Area Workshop*, 428–51.

Review of the Marine Tourism Industry in the Great Barrier Reef World Heritage Area, Parts 1 and 2 1997, Prepared by the Tourism Review Steering Committee with assistance from the Great Barrier Reef Marine Park Authority and the Office of National Tourism.

Threatened Species

Corkeron, P. 1997, 'The status of cetaceans in the Great Barrier Reef Marine Park', in *State of the Great Barrier Reef World Heritage Area Workshop*, 283–87.

Department of Environment 1997, ' Nature Conservation (Whales and Dolphins) Conservation Plan 1997', in *Conservation and management of whales and dolphins in Queensland 1997–2001*, Department of Environment, Brisbane, 2–14.

Environment Australia 1998, *Draft recovery plan for marine turtles in Australia*, Biodiversity Group, Environment Australia, Canberra.

Great Barrier Reef Marine Park Authority 1994, *The Great Barrier Reef, Keeping it Great: A 25 Year Strategic Plan for the Great Barrier Reef World Heritage Area 1994–2019*, Great Barrier Reef Marine Park Authority, Townsville.

Great Barrier Reef Marine Park Authority 1994, *Turtle and Dugong Conservation Strategy for the Great Barrier Reef Marine Park: Issues Paper for Public Comment*, Great Barrier Reef Marine Park Authority, Townsville.

Hulsman, K., O'Neill, P. & Stokes, T. 1997, 'Current status and trends of seabirds on the Great Barrier Reef', in *State of the Great Barrier Reef World Heritage Area Workshop*, 259–82.

Jones, G. P. & Kaly, U. L. 1995, 'Conservation of rare, threatened and endemic marine species in Australia', in *The State of the Marine Environment Report for Australia: Technical Annex 1: The Marine Environment*, eds L. P. Zann & P. Kailola, Great Barrier Reef Marine Park Authority, Townsville, 183–91.

Marsh, H. & Corkeron, P. 1997, 'The status of the dugong in the Great Barrier Reef Marine Park', in *State of the Great Barrier Reef World Heritage Area Workshop*, 231–47.

Robins, J. B. 1995, 'Estimated catch and mortality of sea turtles from the east coast otter trawl fishery of Queensland, Australia', *Biological Conservation*, 74(3), 157–67.

WBM Oceanics Australia & Claridge, G. 1997, *Guidelines for Managing Visitation to Seabird Breeding Islands*, Great Barrier Reef Marine Park Authority, Townsville.

Indigenous Issues

Benzaken, D., Smith, G. & Williams, R. 1997, 'A long way together: the recognition of indigenous interests in the management of the Great Barrier Reef World Heritage Area', in *State of the Great Barrier Reef World Heritage Area Workshop*, 471–95.

Bergin, A. 1993, *Aboriginal and Torres Strait Islander Interests in the Great Barrier Reef Marine Park*, Research Publication no. 31, Great Barrier Reef Marine Park Authority, Townsville.

Cook, C. 1994, 'Aboriginal and Torres Strait Islander traditional hunting and native title', *Reef Research*, 4(2), 6–8.

Great Barrier Reef Marine Park Authority 1994, *The Great Barrier Reef, Keeping it Great: A 25 Year Strategic Plan for the Great Barrier Reef World Heritage Area 1994–2019*, Great Barrier Reef Marine Park Authority, Townsville.

Smyth, D. 1995, 'Indigenous peoples and the marine environment of Cape York Peninsula', in *Indigenous Management of Land and Sea and Traditional Activities of Cape York Peninsula*, ed. J. Cordell, Department of the Environment, Sport and Territories, Canberra, 1–36.

Smyth, D. 1997, 'Recognition of Aboriginal maritime culture in the Great Barrier Reef Marine Park: an evaluation', in *State of the Great Barrier Reef World Heritage Area Workshop*, 496–501.

Williams, R. 1996, 'Who's listening and who's learning? Aboriginal and Torres Strait Islander knowledge of turtle and dugong in the Great Barrier Reef Marine Park regions', in *Ecopolitics IX: Papers and resolutions from a conference held at Northern Territory University, Darwin, 1–3 September 1995*, Northern Land Council, Casuarina, 113–17.

Water Quality and Coastal Development

Creighton, C., Rowland, P. & Capon, S. 1997, 'Managing catchments to minimise downstream effects', in *State of the Great Barrier Reef World Heritage Area Workshop*, 503–21.

Shipping and Oil Spills

Bureau of Transport and Communication Economics 1991, *Major Marine Oil Spills: Risk and Response*, Australian Government Publishing Service, Canberra.

Department of Transport and Communication 1990, *Reefplan: Marine Pollution Contingency Plan for the Great Barrier Reef*, Department of Transport and Communications, Canberra.

Ottesen, P., Sparkes, S. & Trinder, C. 1994, 'Shipping threats and protection of the Great Barrier Reef Marine Park: the role of the particularly sensitive sea area concept', *International Journal of Marine and Coastal Law*, 9(4), 507–22.

Raaymakers, S. 1994, 'Ship sourced oil pollution in the Great Barrier Reef: causes, frequency, response and prevention', in *Hulls, Hazards and Hard Questions, Shipping in the Great Barrier Reef: reducing the risk of spilling oil and other hazardous substances: proceedings of a meeting of experts held in Canberra, Australian Capital Territory 14–15 April 1993*, ed. P. Ottesen, Great Barrier Reef Marine Park Authority, Townsville, (Workshop Series no. 19), 11–24.

Monitoring

Oliver, J., De'ath, G., Done, T., Williams, D., Furnas, M. & Moran, P. (eds) 1995, *Long-term Monitoring of the Great Barrier Reef*, Status Report no. 1, Australian Institute of Marine Science, Townsville.

Sweatman, H. (ed.) 1997, *Long-term Monitoring of the Great Barrier Reef*, Status Report no. 2, Australian Institute of Marine Science, Townsville.

Index

H

I

J

L

M

N

O

P

Q