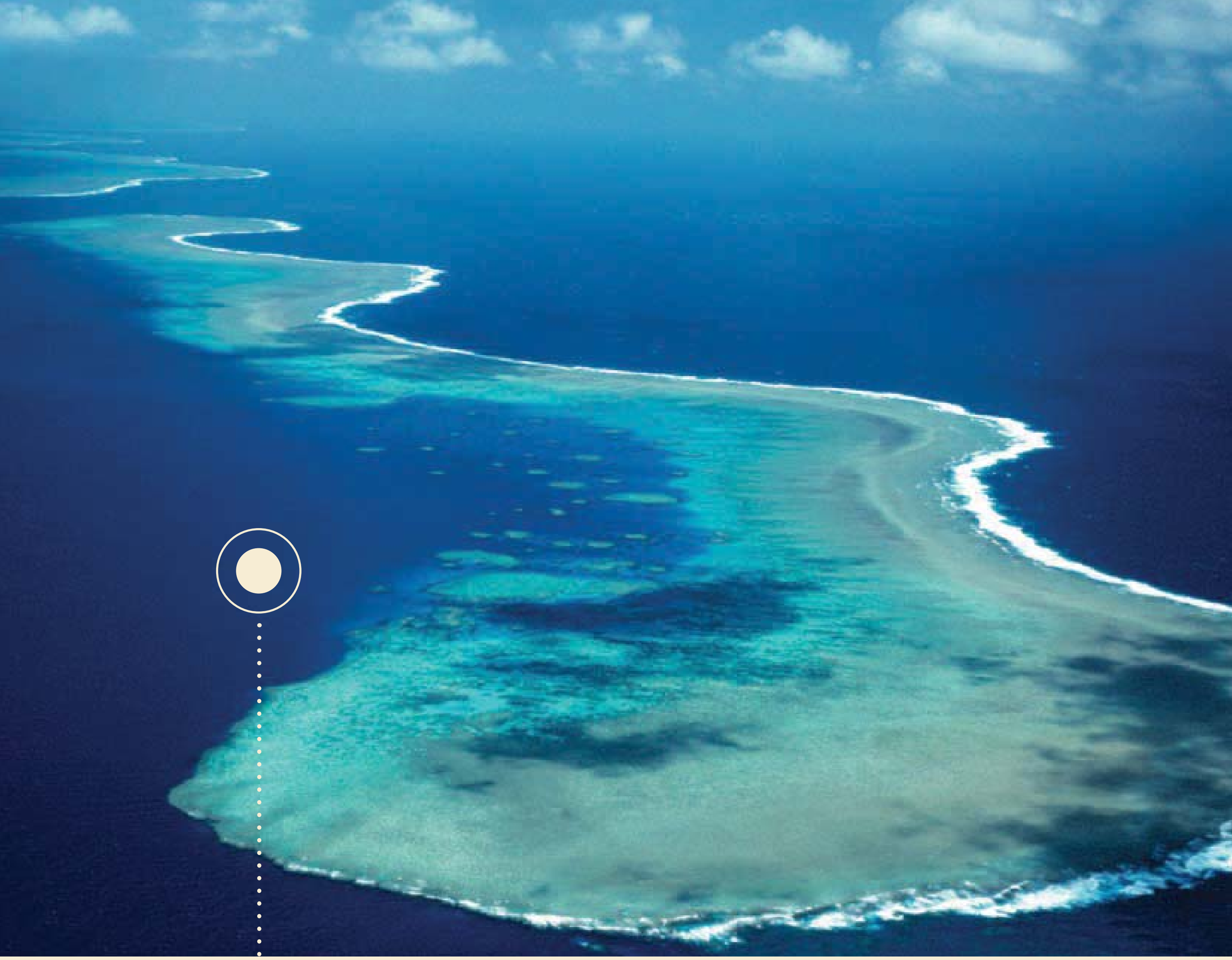

Australian Government

Great Barrier Reef
Marine Park Authority

GREAT BARRIER REEF

OUTLOOK REPORT 2009

Australian Government
Great Barrier Reef
Marine Park Authority

GREAT BARRIER REEF

OUTLOOK REPORT 2009

"…. for here they are reefs of coral rock, rising like a wall almost perpendicularly out of the unfathomable deep, always overflowed at high-water, and at low-water dry in many places; and here the enormous waves of the vast Southern Ocean, meeting with so abrupt a resistance, break, with inconceivable violence, in a surf which no rocks or storms in the northern hemisphere can produce."

\- James Cook, August 1770

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This Report contains photos of Aboriginal and Torres Strait Islanders. Readers of this report should be aware that, in some Aboriginal and Torres Strait Islander communities, seeing images of deceased persons in photographs may cause sadness or distress and, in some cases, offend against strongly held cultural prohibitions.

LETTER OF TRANSMITTAL

Australian Government
Great Barrier Reef
Marine Park Authority

Hon. Peter Garrett AM, MP
Minister for the Environment, Heritage and the Arts
Parliament House
CANBERRA

Dear Minister

I am pleased to provide the ***Great Barrier Reef Outlook Report 2009*** to you as Minister for the Environment, Heritage and the Arts and through you to the Australian Parliament and the people of Australia.

The ***Great Barrier Reef Outlook Report 2009*** has been prepared by the Great Barrier Reef Marine Park Authority based on the best available information. Many people with an interest in the Great Barrier Reef have contributed to its development, including leading Great Barrier Reef scientists, industry representatives and members of regional communities.

This Report fulfils the requirements of Section 54 of the *Great Barrier Reef Marine Park Act 1975*, namely that the Outlook Report contain assessments of the: current health of the ecosystem within the Great Barrier Reef Region and of the ecosystem outside that region to the extent it affects that region; current biodiversity within that region; commercial and non commercial use of that region; factors influencing the current and projected future environmental, economic and social values of that region; existing measures to protect and manage the ecosystem within that region; current resilience of the ecosystem within that region; risks to the ecosystem within that region and long term outlook for the ecosystem within that region. The contents of the Report were independently peer reviewed.

The legislation requires that an Outlook Report be prepared every five years. This first Outlook Report highlights that the Great Barrier Reef is one of the most diverse and remarkable ecosystems in the world and remains one of the most healthy coral reef ecosystems. The Great Barrier Reef Marine Park is considered by many to be a leading example of world's best practice management. Many of the management measures employed in the Great Barrier Reef Region and beyond are improving its resilience, for example the *Great Barrier Reef Marine Park Zoning Plan 2003*.

The Report also highlights challenges for the future, identifying climate change, continued declining water quality from catchment runoff, loss of coastal habitats from coastal development and remaining impacts from lawful fishing and illegal fishing and poaching as the priority issues reducing the resilience of the Great Barrier Reef. It also highlights gaps in information required for a better understanding of ecosystem resilience.

The outlook for the Great Barrier Reef ecosystem is at a crossroad, and it is decisions made in the next few years that are likely to determine its long-term future. Given the strong management of the Great Barrier Reef, it is likely that the ecosystem will survive better under the pressure of accumulating risks than most reef ecosystems around the world.

I commend this Outlook Report to you for tabling in both Houses of the Australian Parliament.

Yours sincerely

Russell Reichelt
Chairman and Chief Executive Officer
Great Barrier Reef Marine Park Authority

30 June 2009

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ACKNOWLEDGEMENTS

The *Great Barrier Reef Outlook Report 2009* was prepared by the Great Barrier Reef Marine Park Authority with assistance and contributions from many others.

A number of Australian and Queensland Government departments and agencies provided information, expertise and comment throughout the development process.

The independent assessment of the existing measures to protect and manage the Great Barrier Reef ecosystem was undertaken by Marc Hockings and Brian Gilligan with early assistance by Bruce Carter.

Many Great Barrier Reef scientists willingly contributed their knowledge and information. J.E.N. (Charlie) Veron undertook a scientific review of the Report and Helene Marsh provided detailed comments on an earlier draft.

Members of the Great Barrier Reef Marine Park Authority's eleven Local Marine Advisory Committees (Cooktown, Douglas, Cairns, Cassowary Coast, Hinchinbrook, Townsville, Whitsunday, Mackay, Capricorn Coast, Gladstone Region, Bundaberg) and four Reef Advisory Committees (Conservation, Heritage and Indigenous Partnerships; Fisheries; Tourism and Recreation; Water Quality and Coastal Development) provided advice on relevant aspects during the Report's development. A number of scientists, industry leaders, interest group leaders, community opinion leaders and Government representatives contributed opinions and information through an Outlook Forum.

An Outlook Reference Group, comprising Richard Kenchington (Chairman), Mark Burgman (Australian Centre of Excellence for Risk Analysis), Col Creighton (independent consultant), Steve Hatfield-Dodds (Department of Climate Change), Bruce Mapstone (Antarctic Climate and Ecosystems Cooperative Research Centre), Sheriden Morris (Reef and Rainforest Research Centre), Peter Oliver (International Water Centre) and Imogen Zethoven (Pew Environment Group) provided valuable advice throughout.

Finally, the contents of the Outlook Report were formally peer reviewed by Richard Beamish (Department of Fisheries and Oceans, Canada), Neil Byron (Productivity Commission, Australia), William Dennison (University of Maryland, USA) and Terry Hughes (ARC Centre of Excellence for Coral Reef Studies, Australia).

EXECUTIVE SUMMARY

The outlook for the Great Barrier Reef ecosystem is at a crossroad, and it is decisions made in the next few years that are likely to determine its long-term future. Unavoidably, future predictions of climate change dominate most aspects of the Great Barrier Reef's outlook over the next few decades. The extent and persistence of the damage to the ecosystem will depend to a large degree on the amount of change in the world's climate and on the resilience of the Great Barrier Reef ecosystem in the immediate future.

This first Outlook Report identifies climate change, continued declining water quality from catchment runoff, loss of coastal habitats from coastal development and remaining impacts from fishing and illegal fishing and poaching as the priority issues reducing the resilience of the Great Barrier Reef. It also highlights gaps in information required for a better understanding of ecosystem resilience.

The Great Barrier Reef is one of the most diverse and remarkable ecosystems in the world and remains one of the most healthy coral reef ecosystems. Nevertheless, its condition has declined significantly since European settlement and, as a result, the overall resilience of the ecosystem has been reduced.

While populations of almost all marine species are intact and there are no records of extinctions, some ecologically important species, such as dugongs, marine turtles, seabirds, black teatfish and some sharks, have declined significantly. Although the declines of loggerhead turtles and dugongs are believed to have halted, there are few examples of increasing populations in species of conservation concern. The obvious example is the humpback whale, which is recovering strongly after being decimated by whaling. Disease in corals and pest outbreaks of crown-of-thorns starfish and cyanobacteria appear to be becoming more frequent and more serious.

Coral reef habitats fluctuate naturally depending on changes in environmental conditions, but they are gradually declining, especially inshore as a result of poor water quality and the compounding effects of climate change. Habitats more remote from human use, such as the continental slope and reefs in the far north are believed to be in very good condition and portions of the lagoon floor are recovering from previous effects of trawling.

Most commercial and non-commercial use of the Great Barrier Reef is dependent on an intact, healthy and resilient ecosystem and it continues to be a significant economic resource for regional communities and Australia. Millions of people continue to enjoy their visits to the Great Barrier Reef. Major changes to the condition of the ecosystem will have social and economic implications.

The Great Barrier Reef Marine Park is considered by many to be a leading example of world's best practice management. However, the effectiveness of management is challenged because complex factors that have their origin beyond the Great Barrier Reef Region, namely climate change, catchment runoff and coastal development cause some of the highest risks to the ecosystem. These factors are playing an increasing role in determining the condition and future of the Great Barrier Reef.

Almost all the biodiversity of the Great Barrier Reef will be affected by climate change, with coral reef habitats the most vulnerable. Coral bleaching resulting from increasing sea temperature and lower rates of calcification in skeleton-building organisms, such as corals, because of ocean acidification are the effects of most concern and are already evident.

The Great Barrier Reef continues to be exposed to increased levels of sediments, nutrients and pesticides, which are having significant effects inshore close to developed coasts, such as causing die-backs of mangroves and increasing algae on coral reefs. Substantial resources are being provided to improve water quality to the Great Barrier Reef, but progress is slow and patchy.

Coastal development is increasing the loss of coastal habitats that support the Great Barrier Reef. Human population increases within the Great Barrier Reef catchment are projected to be nearly two per cent per annum. This will place greater pressure on the ecosystem and increase use of the Great Barrier Reef Region. Integrated planning, knowledge and compliance in managing coastal development are areas highlighted as requiring improvement.

While significant improvements have been made in reducing the impacts of fishing in the Great Barrier Reef, such as bycatch reduction devices, effort controls and closures, important risks to the ecosystem remain from the targeting of predators, the death of incidentally caught species of conservation concern, illegal fishing and poaching. The flow on ecosystem effects of losing predators, such as sharks and coral trout, as well further reducing populations of herbivores, such as the threatened dugong, are largely unknown but have the potential to alter food web interrelationships and reduce resilience across the ecosystem.

Non-extractive uses within the Great Barrier Reef, such as commercial marine tourism, shipping and defence activities, are independently assessed as more effectively managed and are a lower risk to the ecosystem; however the risk of introduced species is likely to increase with projected increases in shipping when global economic recovery occurs. While many of the management measures employed in the Great Barrier Reef Region and beyond are making a positive difference, for example the *Great Barrier Reef Marine Park Zoning Plan 2003*, the ability to address cumulative impacts is weak.

Given the strong management of the Great Barrier Reef, it is likely that the ecosystem will survive better under the pressure of accumulating risks than most reef ecosystems around the world. However, even with the recent management initiatives to improve resilience, the overall outlook for the Great Barrier Reef is poor and catastrophic damage to the ecosystem may not be averted. Ultimately, if changes in the world's climate become too severe, no management actions will be able to climate-proof the Great Barrier Reef ecosystem.

Further building the resilience of the Great Barrier Reef by improving water quality, reducing the loss of coastal habitats and increasing knowledge about fishing and its effects, will give it the best chance of adapting to and recovering from the serious threats ahead, especially from climate change.

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ABOUT THIS REPORT

The Great Barrier Reef Marine Park Act sets out what the Outlook Report must contain.

The Outlook Report focuses on all marine areas below low water.

In 2006, the Australian Government resolved that decision making for long-term protection of the Great Barrier Reef should be underpinned by a periodic Outlook Report. The Report would be a regular and reliable means of assessing performance in an accountable and transparent manner and a key input for any future changes to zoning plans and the consideration of broader issues by government.

The *Great Barrier Reef Marine Park Act 1975* was amended in 2007 requiring the Great Barrier Reef Marine Park Authority to prepare an Outlook Report for the Great Barrier Reef Region every five years (Appendix 1). The Act stipulates that the Report must be given to the Minister for the Environment, Heritage and the Arts for tabling in both houses of the Australian Parliament.

This is the first Great Barrier Reef Outlook Report.

Scope of the Outlook Report

The area examined in this Report is the Great Barrier Reef Region as defined in the *Great Barrier Reef Marine Park Act 1975*. The Great Barrier Reef Region covers the area of ocean from the tip of Cape York in the north to past Lady Elliot Island in the south, with mean low water as its western boundary and extending eastwards a distance of between 70 and 250km (see Map 1). It includes about 70 Commonwealth-owned islands. However, the majority of islands in the Great Barrier Reef are owned by the Queensland Government or privately and are not included in the Great Barrier Reef Region.

The Region's boundaries match those of the Great Barrier Reef Marine Park, except the Region also includes the areas around major ports.

The Outlook Report aims to assess all parts of the ecosystem within the Region, including everything from mangroves and seagrass meadows to coral reefs and the open ocean. For the purposes of this Report all these components are referred to as the Great Barrier Reef ecosystem or simply the Great Barrier Reef.

Where it is relevant to the Great Barrier Reef ecosystem, the Report also looks beyond the boundaries of the Region and includes information about adjacent islands, neighbouring marine areas and the Great Barrier Reef catchment.

The Outlook Report is a summary of the past and present condition of the Great Barrier Reef and presents its possible future. The Act does not provide for the Outlook Report to make recommendations about future protection or management initiatives.

All of the habitats and species of the Great Barrier Reef Region are considered in this Report, including species of conservation concern such as the hawksbill turtle.

[1] Department of the Environment and Heritage 2006, Review of the *Great Barrier Reef Marine Park Act 1975*, Review Panel Report. Department of the Environment and Heritage, Canberra, Australia.

Map 1 The Great Barrier Reef Region

The Outlook Report is a report about the entire Great Barrier Reef Region, plus adjacent ecosystems where relevant.

Structure of the Outlook Report

The Outlook Report assesses the current state of the Great Barrier Reef ecosystem's environmental, social and economic values, examines the pressures and current responses and finally considers the likely outlook. It is structured around the eight assessments required by the Act, with each assessment forming a chapter of the Report.

Assessment approach

For each of the assessments required under the Act, a set of Assessment Criteria allow an ordered analysis of the available evidence. An Assessment Summary at the end of each chapter summarises the outcomes of the assessment for each criterion considered. A series of grading statements guide the allocation of a grade for each component examined in the assessment, as well as an overall grade for each Assessment Criterion. The grading allocated is a 'grade of best fit', based on a qualitative assessment of the available evidence. The '?' symbol indicates that there is little information available on which to base the grade. The grade allocated is in relation to the Great Barrier Reef on its own, not in comparison to other reefs around the world.

This approach has been developed specifically for the Great Barrier Reef Outlook Report to meet the legislative requirements. It is intended that future Outlook Reports will follow the same process so that changes and trends can be tracked over time.

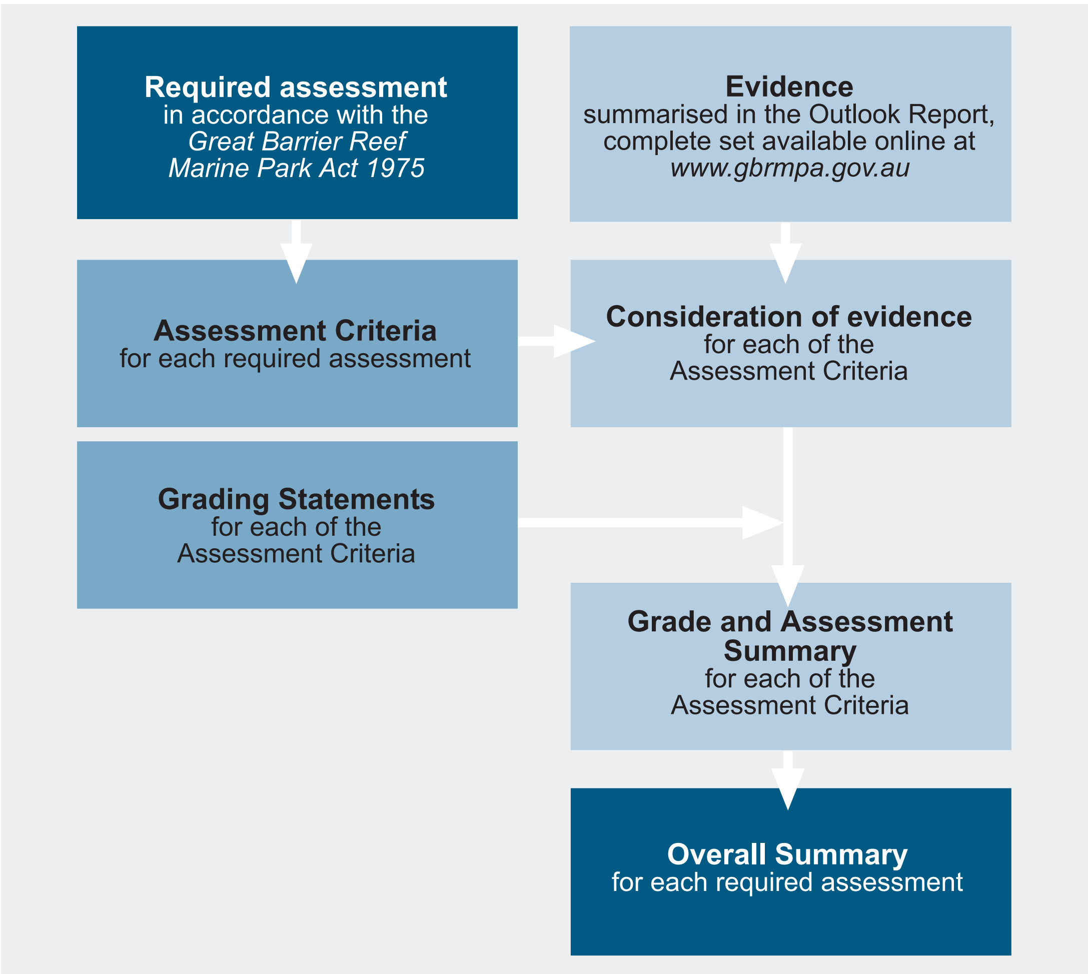
Evidence used

This Outlook Report contains the key evidence for the assessments required under the Act. As it is the first Outlook Report, it also provides contextual information about the Great Barrier Reef, its ecosystem, use and management.

The information featured in the Report is only a small portion of all that is known about the Great Barrier Reef Region. No new research was undertaken as part of developing this Report; rather, the evidence used is derived from existing research and information sources. It was drawn from the best available published science and selected based on:

- relevance to the required assessments
- duration of study
- extent of area studied
- reliability (such as consistency of results across different sources, peer-review and rigour of study).

The required assessments are structured around Assessment Criteria.



The Outlook Report is based on the best available evidence.

You can explore the information used to develop the Outlook Report online at www.gbrmpa.gov.au

The sources of the evidence directly used in each chapter are cited at the end of that chapter.

The complete set of evidence used to develop the Great Barrier Reef Outlook Report is available online at *www.gbrmpa.gov.au*.

The evidence used to develop this Report is the best available up to the end of 2008. In some cases, new information that became available after that date has been included where it was considered to make a significant difference to a key finding of the Report.

Despite the volume of information available, there remain many aspects of the ecosystem, its uses and threats (in particular cumulative and ecosystem effects) about which little are known. Significant information gaps are noted in the text. Information from other parts of the world is included for comparison or illustrative purposes.

Developing the Outlook Report

The Great Barrier Reef Outlook Report has been prepared by the Great Barrier Reef Marine Park Authority.

Many people and organisations have contributed to development of the Outlook Report.

A number of Australian and Queensland Government agencies, researchers, industry representatives and members of the public contributed to its development (Appendix 2). The Great Barrier Reef Marine Park Authority's four Reef Advisory Committees (external experts who provide independent advice on critical issues) and 11 Local Marine Advisory Committees (committees centred on regional centres along the coast) provided advice throughout the Report's development.

The Great Barrier Reef Marine Park Authority held community workshops to learn about changes to the Great Barrier Reef by listening to community members' stories of the past. In addition, an Outlook Forum attended by 42 participants including scientists, leaders from industry, interest groups and the community and government representatives developed likely 'outlooks' for the Great Barrier Reef.

Throughout development of the Report, an Outlook Reference Group comprising eight experts in environmental reporting, protected area management and communication provided advice and guidance on information available, assessment methods and community engagement and presentation.

Two experts in protected area management, monitoring and evaluation, public policy and governance were commissioned to undertake an independent assessment of existing protection and management. Their report forms the basis of the assessment of existing measures to protect and manage the Great Barrier Reef ecosystem (Chapter 6).

Finally, four reviewers appointed by the Minister for the Environment, Heritage and the Arts independently reviewed the contents of the Outlook Report. These reviewers are recognised national and international experts with biophysical and/or socio-economic expertise and achievements, including conducting high level policy and scientific reviews. Their comments were considered and incorporated where appropriate in finalising this Report.

THE GREAT BARRIER REEF

CHAPTER ONE

"The Great Barrier Coral Reef of Australia, the marvellous structure and extent of which were first made known to the world through the explorations of Captain Cook, is one of the wonders of the universe."

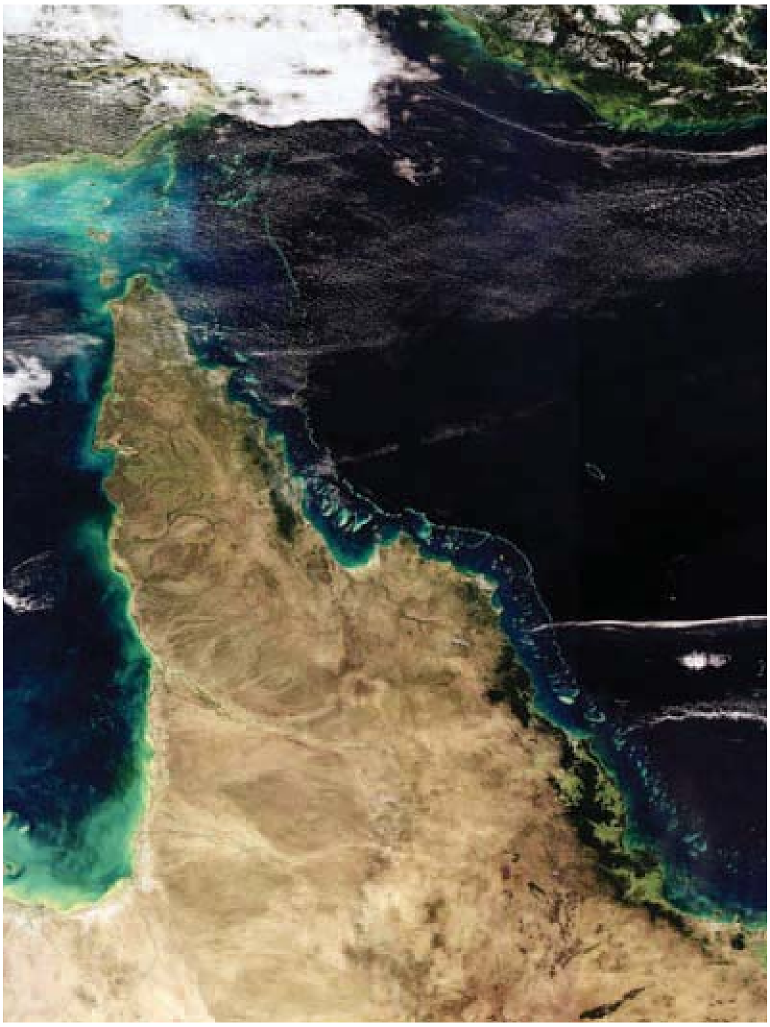
W. Saville-Kent 1893
Biologist, businessman and pioneer fisheries manager

1 THE GREAT BARRIER REEF

The Great Barrier Reef is the largest and best known coral reef ecosystem in the world, spanning a length of 2300 km along two-thirds of the east coast of Queensland. The reefs of the Great Barrier Reef - almost 3000 in total - represent about 10 per cent of all the coral reef areas in the world.[1]

The Great Barrier Reef is a Queensland and Australian icon and part of the country's identity.

Virtually all groups of marine plants and animals are abundantly represented in the Great Barrier Reef, with thousands of different species living there.



The Great Barrier Reef from space
The Great Barrier Reef hugs the east coast of Queensland, Australia. Its variety of reefs is substantially greater than in any other place on Earth. (Photo courtesy of the European Space Agency)

1.1 A great Australian icon

The Great Barrier Reef is one of the world's premier natural resources and is a national and international icon, famous for its beauty and vast scale. By universal acclaim, it is a place of grandeur to be cherished by people of all nations and protected from threats.

Not surprisingly, the Great Barrier Reef has attracted immense national and international interest resulting in many hundreds of popular books, articles, guides and television documentaries about it and the life it contains. The number of scientific articles on aspects of the Great Barrier Reef ecosystem now numbers in the tens of thousands.

The Great Barrier Reef is an integral part of the Australian national identity. Around half of the residents of Great Barrier Reef coastal communities and about 10 per cent of residents in southern capital cities visited the Great Barrier Reef in 2007.[2] It attracts expressions of national pride in the visual arts, literature and education, plus during national events.

The Great Barrier Reef was part of the Torch Relay for the 2000 Olympic Games held in Sydney, Australia. (Photo courtesy of the Quicksilver Group)

When under threat, the Great Barrier Reef also attracts widespread public concern for its conservation.

This interest is not confined to Australia. Like the Amazon rainforest, the Great Barrier Reef is known throughout the world as one of the greatest natural ecosystems of our planet. When so many of the world's most valued places of natural wilderness have been degraded within the space of a few generations, the intangible value the Great Barrier Reef continues to increase.

Throughout the late 1960s and into the 1970s, under the slogan *Save the Barrier Reef*, the Great Barrier Reef became the subject of the biggest conservation campaign in Australian history.[3] [4] [5] In 1974 a Royal Commission into oil drilling on the Great Barrier Reef highlighted the scarcity of scientific knowledge about the ecosystem, as well as the lack of a dedicated regulatory authority to manage it. This activity culminated in 1975 with the *Great Barrier Reef Marine Park Act* establishing the Great Barrier Reef Marine Park Authority and the Great Barrier Reef Marine Park.

1.2 Protected as a marine park

Areas of the Great Barrier Reef Region have been progressively included in the Commonwealth Great Barrier Reef Marine Park since the late 1970s. Today almost all of the Great Barrier Reef ecosystem is included within the Great Barrier Reef Marine Park which extends over 2300km along the coast of Queensland and covers approximately 344 400 km^2 (see Map 1). This Commonwealth Marine Park is complemented by the Great Barrier Reef Coast Marine Park in adjacent Queensland waters.

1.2.1 A multiple use area

The Great Barrier Reef Marine Park is a multiple use marine park, supporting a wide range of uses, including commercial marine tourism, fishing, ports and shipping, recreation, scientific research and Indigenous traditional use. It brings billions of dollars into Australia's economy each year, and supports more than 50 000 jobs.[6]

1.2.2 Marine Park management

The Great Barrier Reef Marine Park Authority is responsible for the care and development of the Great Barrier Reef Marine Park. Field management is a partnership between the Authority and the Queensland Department of Environment and Resource Management, complemented by other Australian and Queensland Government agencies. Management is enhanced through partnerships with stakeholders, scientists and members of the Great Barrier Reef coastal community.

The Great Barrier Reef ecosystem benefits many industries and the community.

Within the Great Barrier Reef Marine Park, a number of activities are strictly prohibited (such as mining and oil drilling) and there is careful management of all other activities (such as fishing, commercial marine tourism and shipping operations). A range of measures are employed to manage the various uses of the Marine Park and to protect its values. For example, a Zoning Plan defines what activities can occur in which locations (figure 1.1), both to protect the marine environment and to separate potentially conflicting activities.

GBRMPA Zoning
(see relevant *Zoning Plans* and *Regulations* for details)

	General Use Zone	Habitat Protection Zone	Conservation Park Zone	Buffer Zone	Scientific Research Zone *	Marine National Park Zone	Preservation Zone
Aquaculture	Permit	Permit	Permit *	✕	✕	✕	✕
Bait netting	✓	✓	✓	✕	✕	✕	✕
Boating, diving, photography	✓	✓	✓	✓	✓ *	✓	✕
Crabbing (trapping)	✓	✓	✓ *	✕	✕	✕	✕
Harvest fishing for aquarium fish, coral and beachworm	Permit	Permit	Permit *	✕	✕	✕	✕
Harvest fishing for sea cucumber, trochus, tropical rock lobster	Permit	Permit	✕	✕	✕	✕	✕
Limited collecting	✓ *	✓ *	✓ *	✕	✕	✕	✕
Limited spearfishing (snorkel only)	✓	✓	✓ *	✕	✕	✕	✕
Line fishing	✓ *	✓ *	✓ *	✕	✕	✕	✕
Netting (other than bait netting)	✓	✓	✕	✕	✕	✕	✕
Research (other than limited impact research)	Permit	Permit	Permit	Permit	Permit	Permit	Permit
Shipping (other than in a designated shipping area)	✓	Permit	Permit	Permit	Permit	Permit	✕
Tourism programme	Permit	Permit	Permit	Permit	Permit	Permit	✕
Traditional use of marine resources	✓ *	✓ *	✓ *	✓ *	✓ *	✓ *	✕
Trawling	✓	✕	✕	✕	✕	✕	✕
Trolling	✓ *	✓ *	✓ *	✓ *	✕	✕	✕

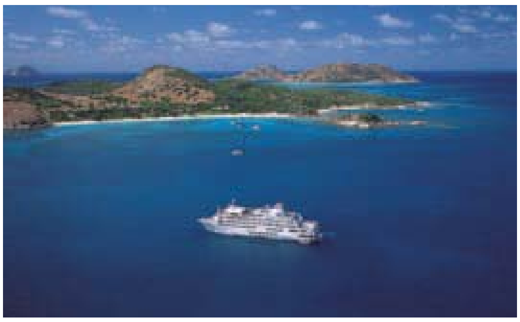
PLEASE NOTE: This guide provides an introduction to Zoning in the Great Barrier Reef Marine Park. Relevant Great Barrier Reef Marine Park Zoning Plans should be consulted for confirmation of use or entry requirements.

* Additional restrictions / conditions apply.

ACCESS TO ALL ZONES IS PERMITTED IN AN EMERGENCY.

Figure 1.1 | Activities allowed under the Zoning Plan

Zones delineate where particular activites are permitted under the *Great Barrier Reef Marine Park Zoning Plan 2003.*



Cruise ship at Lizard Island.

The Great Barrier Reef is a vast, multiple use, Marine Park.

Mangroves

1.3 Heritage values

1.3.1 Significance to Traditional Owners

For the Great Barrier Reef, there are about 70 Aboriginal and Torres Strait Islander Traditional Owner clan groups that hold a range of past and present heritage values for their land and sea country, and for surrounding sea countries. These values may be cultural, spiritual, economic, social or physical, and demonstrate continuing connections with the Great Barrier Reef Region and its natural resources.

Spinner dolphins

1.3.2 World Heritage

The Great Barrier Reef was inscribed on the World Heritage List in 1981, the first coral reef ecosystem in the world to have this distinction and the only such coral reef region that has ever qualified on all four natural criteria, namely:

The Great Barrier Reef is a World Heritage Area, recognised for its great diversity of species and habitats.

- be outstanding examples representing the major stages of Earth's history or significant geomorphic or physiographic features
- be outstanding examples representing significant ongoing ecological and biological processes
- contain superlative natural phenomena or areas of exceptional natural beauty and aesthetic importance
- contain important and significant habitats for *in situ* conservation of biodiversity, including threatened species.

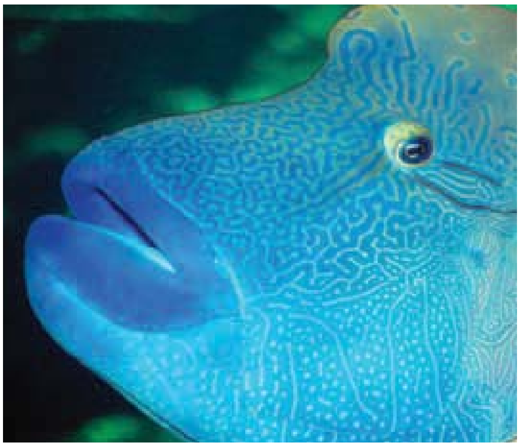
This recognition continues to highlight the international significance of the Great Barrier Reef; it also carries an obligation and responsibility to protect and conserve its values for all future generations and to present its values to the world.

Nudibranch

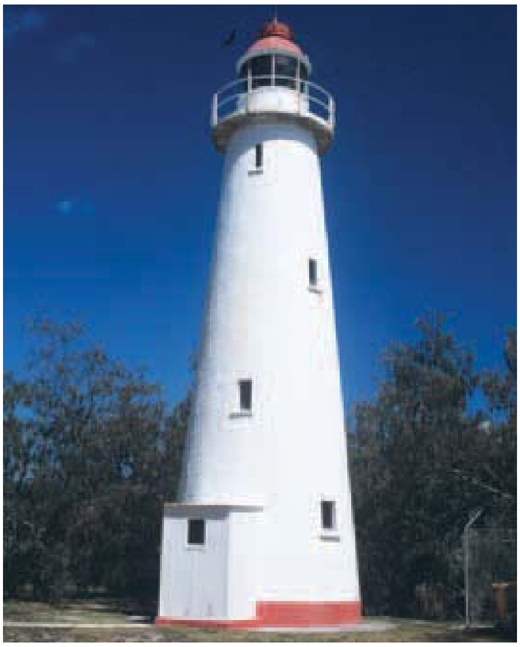
Red reef lobster

Whale shark

Red-footed booby



Humphead Maori wrasse



The historical significance of Lady Elliot Island Lighthouse has been recognised through its inclusion on the Commonwealth Heritage List.

1.3.3 National heritage

In May 2007, existing Australian World Heritage properties (such as the Great Barrier Reef) were transferred on to the National Heritage List for their World Heritage values. In addition, five Commonwealth Heritage places within the Great Barrier Reef Region and many places of historical significance including lighthouses and shipwrecks are managed to protect heritage values. There are also many places of particular historical importance, such as Endeavour Reef where Captain Cook ran aground and was obliged to discard his ship's cannons.

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BIODIVERSITY

CHAPTER TWO

"... meeting with many curios fish and mollusca besides corals of many species, ... I have often lamented that we had not time to make proper observations upon this curios tribe of animals but we were so entirely taken up with the more conspicuous links of the chain of creation as Fish, Plants, Birds, etc, etc that it was impossible."

Joseph Banks, 1770
Botanist, explorer and member of
Cook's first voyage of discovery

"an assessment of the current biodiversity within ..." the Great Barrier Reef Region, Section 54(3)(b) of the *Great Barrier Reef Marine Park Act 1975*.

2 BIODIVERSITY

2.1 Background

The Great Barrier Reef Region is vast, covering 14 degrees of latitude and extending 70 to 250km from the coast. It is home to thousands of coral and other invertebrate species, bony fish, sharks, rays, marine mammals, marine turtles, sea snakes, seabirds plus a wide variety of other animals, as well as algae and other marine plants. It provides particularly important habitat for species of conservation concern such as dugongs, whales, dolphins, sharks and marine turtles. It is this biodiversity that builds such a remarkable ecosystem, as well as supporting human use of the Great Barrier Reef.

Biodiversity is the variety amongst living organisms.

Biodiversity is the variety among all plants and animals. It encompasses all living things, from microbes and single cell algae to marine turtles and whales, and their habitats. Importantly, it is not just a measure of how many species there are. Rather, it encompasses all natural variation - from genetic differences within one species to variations across a habitat or a whole ecosystem.

A gradient across the continental shelf dominates the Region's ecology with dramatic changes in the Great Barrier Reef ecosystem from the inshore coastal zone to the offshore outer reefs. As a result, most habitat and species variation occurs across the Great Barrier Reef rather than down its length.[1] This gradient is due to the exceptional width of most of the continental shelf which allows for strong variations in factors such as depth, nutrients, sediments and light levels. For example, the relatively sediment tolerant[2] coral species in the shallow inshore reef ecosystems create very different habitats from those of the wave-exposed outer margin where the water is clear and deep.

Factors that contribute to longitudinal variation along the Great Barrier Reef ecosystem include bathymetry - the seafloor in the Great Barrier Reef lagoon is about twice as deep in the south than in the north; geology; climate; ocean circulation; tidal currents and tidal patterns.

Table 2.1 Area of major types of habitat in the Great Barrier Reef Region

Habitat type	Percentage of the Region
Coral reefs	7%
Seagrass, shoals and sandy or muddy seabed (up to 200m deep)	61%
Continental slope (200-1000m deep)	15%
Deep oceanic waters (deeper than 1000m)	16%
Islands	1%

The Great Barrier Reef supports a wide variety of habitats.

Figure 2.1 Major habitats of the Great Barrier Reef

There is a wide variety of inter-connected habitats within the Great Barrier Reef ecosystem.

2.1.1 Habitats of the Great Barrier Reef

The Great Barrier Reef supports a wide variety of habitats from mangroves and beaches to deep open water (figure 2.1). Within these habitats there is great variation, with 70 different biological regions recognised, 30 within the reefs themselves and 40 in the surrounding areas[3 4] (figures 2.2 and 2.3).

Coral reefs are the best known part of the Great Barrier Reef Region, yet they make up only seven per cent of its area. Over one-third of the Great Barrier Reef Region is in fact continental slope and extremely deep oceanic habitats (table 2.1).

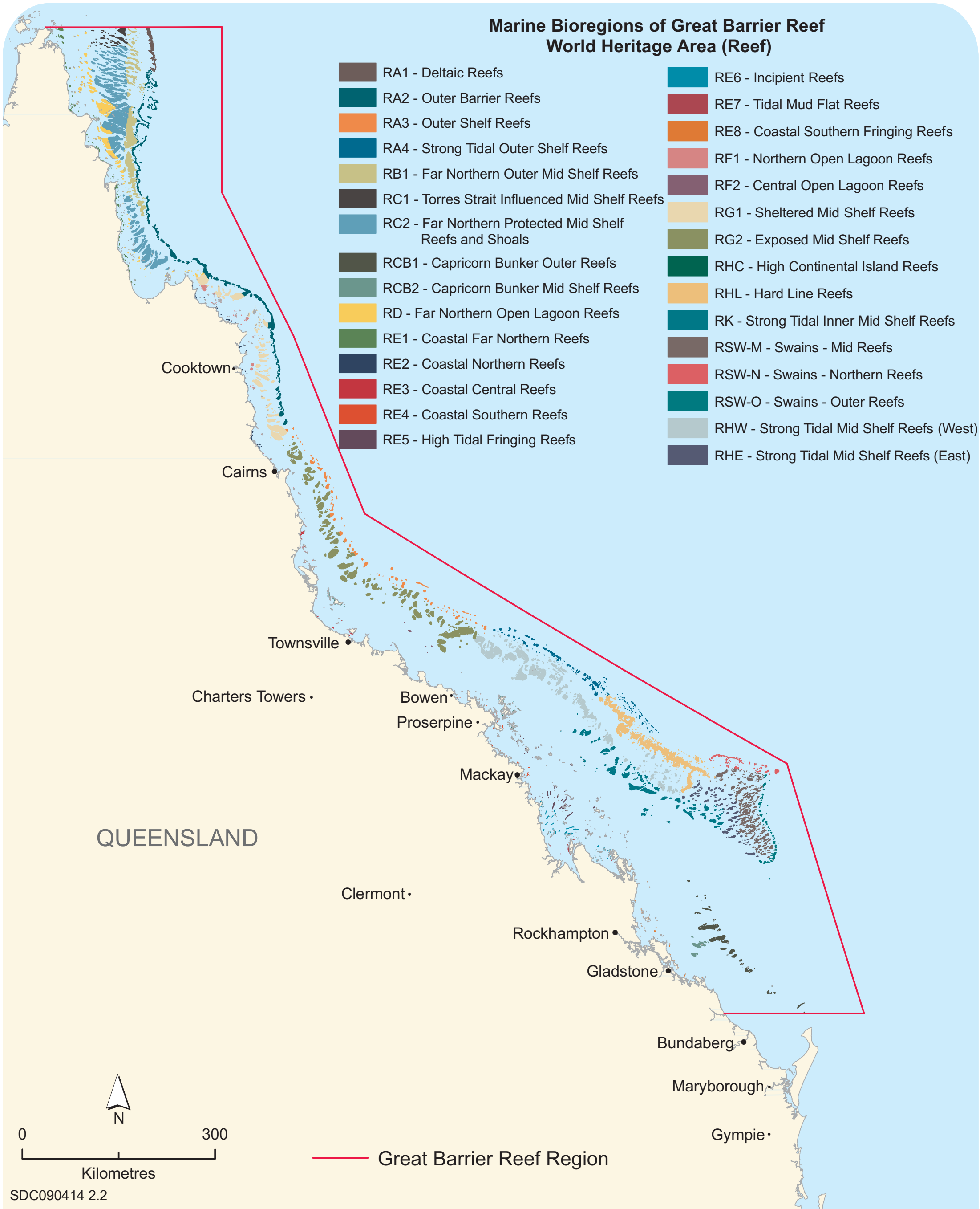


Figure 2.2 **Reef bioregions of the Great Barrier Reef[3 4]**

Thirty reef bioregions have been identified in the Great Barrier Reef Region. Each bioregion represents an area with distinct plant and animal assemblages and physical features.

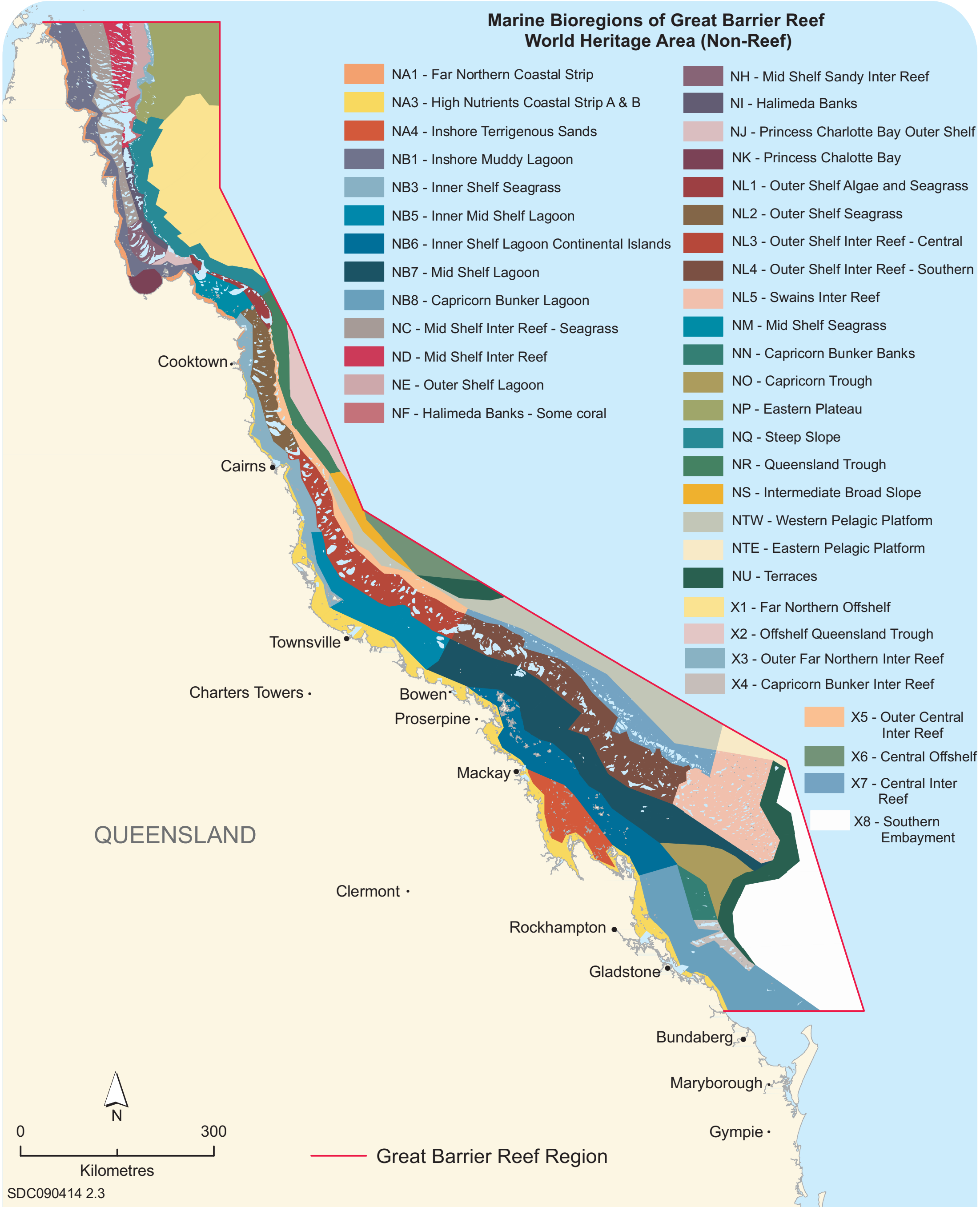


Figure 2.3 Non-reef bioregions of the Great Barrier Reef[3 4]

Forty non-reef bioregions have been identified in the Great Barrier Reef Region. These bioregions cover all the areas between and beyond the reef areas. Each bioregion represents an area with distinct plant and animal assemblages and physical features.

2.1.2 Species of the Great Barrier Reef

The Great Barrier Reef is one of the world's most diverse marine ecosystems.

There are many thousands of plant and animal species found in the Great Barrier Reef ecosystem (table 2.2). They range in size from microscopic plankton to whales weighing more than 100 tonnes, and include both benthic organisms such as corals or seagrasses that live on the seafloor and pelagic organisms such as plankton and many fishes that live in the water column itself.

Some species in the Great Barrier Reef are classified as species of conservation concern. This means that they are protected by law or require special management. These include:

Table 2.2 Plants and animals of the Great Barrier Reef[5 6]

Thousands of species make up the Great Barrier Reef ecosystem. Nowhere near all of them have been identified and described.[7] For some, the number of species recorded is provided, for others the most up-to-date estimate is given.

Plants and animals of the Great Barrier Reef	Number of species recorded
Marine macroalgae	630
Mangroves	39
Seagrass	15
Worms	at least 500
Crustaceans	about 1300
Echinoderms	630
Sponges	at least 2500
Molluscs	as many as 3000
Soft corals and sea pens	at least 150
Hard corals	411
Bony fish	1625
Sharks and rays	134
Sea snakes	14 breeding species
Marine turtles	6
Crocodiles	1
Seabirds	22 nesting species
Dugongs	1
Whales and dolphins	more than 30

Threatened species Twenty-seven marine species listed as 'vulnerable', 'endangered' or 'critically endangered' under Australian and Queensland Government legislation occur in the Great Barrier Reef. There are seven marine reptiles, six marine mammals, six sharks and eight seabirds (table 2.3). For many of these the Great Barrier Reef is vital to their survival and recovery.

Iconic species These are well-known plants or animals, such as sea snakes, seahorses, pipefish, Maori wrasse, whales and dolphins, which often need specific management in the Great Barrier Reef.

'At risk' species These species are not necessarily protected by legislation, but are facing serious pressure and require special management. Examples include most sharks and rays, triton shells and giant clams.

Table 2.3 Threatened marine species known to occur in the Great Barrier Reef Region

Marine reptiles	Seabirds
Flatback turtle	Grey-headed albatross
Green turtle	Herald petrel
Hawksbill turtle	Little tern
Leatherback turtle	Northern giant petrel
Loggerhead turtle	Red-tailed tropicbird
Olive ridley turtle	Sooty albatross
Estuarine crocodile	Southern giant petrel
	Wandering albatross
Marine mammals	**Sharks**
Blue whale	Speartooth shark
Dugong	Freshwater sawfish
Fin whale	White shark
Humpback whale	Green sawfish
Sei whale	Grey nurse shark
Subantarctic fur seal	Whale shark

2.2 Current state and trends of habitats to support species

2.2.1 Coastal habitats

Throughout most of the Great Barrier Reef Region, the coastal zone (within about five to 50km from the coastline) is strongly affected by runoff of terrestrial sediments and nutrients. As most rivers discharging into the Great Barrier Reef are strongly seasonal according to 'wet' and 'dry' seasons (in summer and winter respectively) and have high rates of flow during peak rainfall, they have a major influence on nearshore seabed communities. Most continental islands, mangrove forests and seagrass meadows occur within, or adjacent to, the coastal zone.

Islands The Great Barrier Reef has more than 900 islands, comprising a great variety of cays and continental islands. Most cays and continental islands are found in inshore and mid-shelf regions. The cays of the Great Barrier Reef (such as Heron Island in the south and Raine Island in the far north) are composed entirely of sand, rubble and beach rock, all originally derived from coral, foraminifera and coralline algae debris.[8] They are continually

The Great Barrier Reef is a refuge for many species of conservation concern.

About half of the islands are within protected areas, some have been partially developed.

changing shape and size as part of natural cycles of deposition and erosion. Continental (or 'high') islands, which may form extensive archipelagos, are generally in the central section of the Region. With projected sea level rise as a result of climate change, the condition of islands is likely to change.

Within the Great Barrier Reef Region, the role of islands in supporting marine species is well recognised.[8] All islands of the Great Barrier Reef are part of the Great Barrier Reef World Heritage Area. About half are within protected areas, such as marine or national parks. A small number of islands within the Great Barrier Reef Region are a focus for tourism developments and activities.

In some areas, changes in coastal dynamics and reclamation of marine areas have altered the beach habitats of the Great Barrier Reef.

Beaches Beaches are an important part of the coastal zone, especially as nesting grounds for seabirds and marine turtles. They also have an important recreational role for visitors to the Great Barrier Reef. Beaches are highly dynamic habitats.[9] They have natural cycles of accretion and erosion driven by tides, winds, waves and storms. They are therefore sensitive to any change in coastal water movement (for example through the installation of groins and seawalls[10]) and are prone to degradation from coastal construction activities. Many beaches close to urban areas along the Great Barrier Reef coast have been altered by the installation of structures and the reclamation of marine areas.

Mangroves Once considered undesirable swamps, mangrove forests are now justly regarded as places of interest and beauty. Mangroves provide nursery grounds for many pelagic and nearshore fish species and are the habitat for an extensive array of nearshore marine life as well as birds and other

The overall area of mangrove forest adjacent to the Great Barrier Reef appears to be generally stable except where there is significant coastal development.

Beaches, especially on islands such as Raine Island, are important nesting areas for threatened marine turtle species. (Photo courtesy of J.E.N. Veron)

terrestrial wildlife.[11] Mangroves also play a major role in the prevention of coastal erosion and act as a filter system for water before it enters the Great Barrier Reef.

Mangrove forests dominate much of the shoreline of the coastal zone. They have been cleared along some sections of coast, but have successfully re-established on others (refer figure 5.19). Mangrove communities are dynamic and have been known to die-back at times (e.g. Pioneer River, Shoalwater Bay). The Pioneer River dieback is likely to have been caused by herbicide runoff.[12]

Seagrass meadows Seagrasses are flowering plants and are the main food source for dugongs and green turtles. They are also habitat constructors and provide nursery areas for juvenile prawns such as tiger and endeavour prawns, and fishes, crabs and marine crayfish, all of which are important to commercial and recreational fisheries.[13] Approximately 6000km^2 of seagrass meadows occur along the Queensland coast, both in shallow inshore areas and deeper water. An unknown but larger area probably occurs in the

Recollections of inshore seagrass meadows

Dave Nissen has been a **commercial fisher** and once ran tourist charters. A born adventurer, he is a keen observer of changes in the inshore reef and habitat. He describes how, on a local scale, things have changed at one of his favourite spots around Mission Beach since the 1950s:

> *"I was just thinking the other day, at Bingil Bay there used to be seagrass right up to the edge of the beach there, the low tide mark and we used to run around spearing Moreton Bay bugs with spears made out of push bike spokes. You wouldn't even see a Moreton Bay bug now. Gone, and the seagrass, as well, you know."*

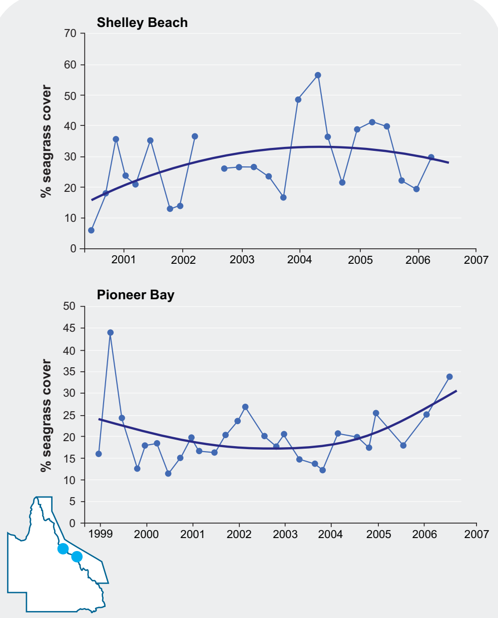


Figure 2.4 **Changes in coastal intertidal seagrass habitats**[16]

Shelley Beach near Townsville and Pioneer Bay in the Whitsundays are examples of how the density of coastal intertidal seagrass habitat fluctuates over time. *Halodule uninervis* and *Halophila ovalis* were monitored at both sites. *Zostera capricorni* was also monitored at Pioneer Bay. The dark blue line shows the overall trend of seagrass cover at each site.

deeper, offshore waters of the Great Barrier Reef lagoon.[14 15]

On a Reef-wide scale, the overall area of seagrass meadows is considered to be relatively stable over the past 20 years.[16] Nevertheless, they fluctuate widely on local scales (figure 2.4) as a result of climate variability (such as exposure at low tides in hot, dry years) and local event-related changes (such as floods). Seagrass habitat has been lost through land reclamation. For example, in recent years approximately 20 hectares has been lost through projects in the Townsville and Airlie Beach areas.[16] Seagrass meadows are sensitive to sediments from flood events.[17] They are also sensitive to nutrient inputs, for example at Green Island where seagrass cover has increased over a 50 year time period.[18]

2.2.2 Coral reefs

Coral reefs may be only seven per cent of the area of the Great Barrier Reef, but they provide a vitally important habitat for an enormous diversity of plants and animals, such as small fish (e.g. clownfish), invertebrates (e.g. clams, nudibranchs), and stand out as the iconic attraction for most reef users.

Changes in seagrass communities appear to be mainly due to natural cycles of decline and recovery.

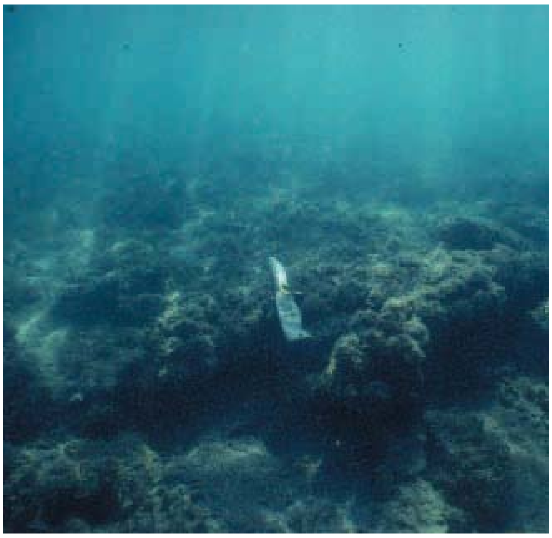
Available evidence indicates that the overall status of coral reefs on the Great Barrier Reef is relatively good, but is likely to be declining slightly, especially in inshore areas. However, the picture is not simple or clear cut, with reefs in different regions showing enormous differences in trends, including both increases and declines. This is because coral reefs are naturally very dynamic habitats, with cycles of disturbance and recovery. The challenge is to detect whether there are long-term trends hidden within natural cycles. A related challenge is the lack of systematic monitoring data prior to the mid-1980s, making assessment of long-term changes very difficult.

Ribbon reefs form an almost continuous chain in the far northern Great Barrier Reef.

Assessments of coral reef status and trends are usually based on the amount of coral on a reef, usually measured in terms of per cent cover. Although there are scientific limitations to this approach[19], it is one of the few which can be effectively applied at the very large scales of the Great Barrier Reef.[20 21]

Trends in coral cover are difficult to interpret.

The most comprehensive, long-term coral cover dataset for the Great Barrier Reef comes from the Australian Institute of Marine Science Long-Term Monitoring Program which has systematically monitored coral cover on a large number of reefs across and along the Great Barrier Reef since 1985. Data are collected using two different methods, manta tow surveys (starting in 1985) and video transects (starting in 1991).



Coral cover and reef status *Scientists use the per cent of a reef covered by coral as an indicator of the overall status of a reef. Of course, different reefs naturally have different amounts of coral, but long-term or systematic declines in coral cover (such as in the photo on the right) are a serious warning sign. (Photos courtesy of L. McCook)*

The overall status of coral reef habitats remains relatively good, with a likely small decline in overall coral cover.

The major conclusion from the Long-Term Monitoring Program is that coral cover has undergone a wide range of changes, including dramatic increases and decreases on different reefs, and that there is no strong, consistent overall trend across the Great Barrier Reef (figures 2.5 and 2.6). This is a reflection of the vast size of the ecosystem, the number and diversity of reef types, and the circumstances and events that affect them. Importantly, patterns change markedly over time even within one reef, so that long-term trends also depend strongly on the period chosen for analysis; this explains some of the differences between the manta tow and video transect datasets.

The overall trend from the video transect data indicates a very slight increase in coral cover of 0.24 per cent per year from 1992 to 2008. However, the overall long-term trend from the manta tow data indicates a small decrease in coral cover of -0.29 per cent per year between 1986 and 2008. Whilst this may seem like a small change relative to the large changes occurring on individual reefs, it is potentially very important as it reflects changes over a very large scale; small changes over such large scales can rapidly accumulate to a very serious decline.

Reef scientists measuring coral abundance, using manta tow (left) and video transects (right). Each method has advantages and disadvantages, but combining both methods provides a double check on the reliability of the data.

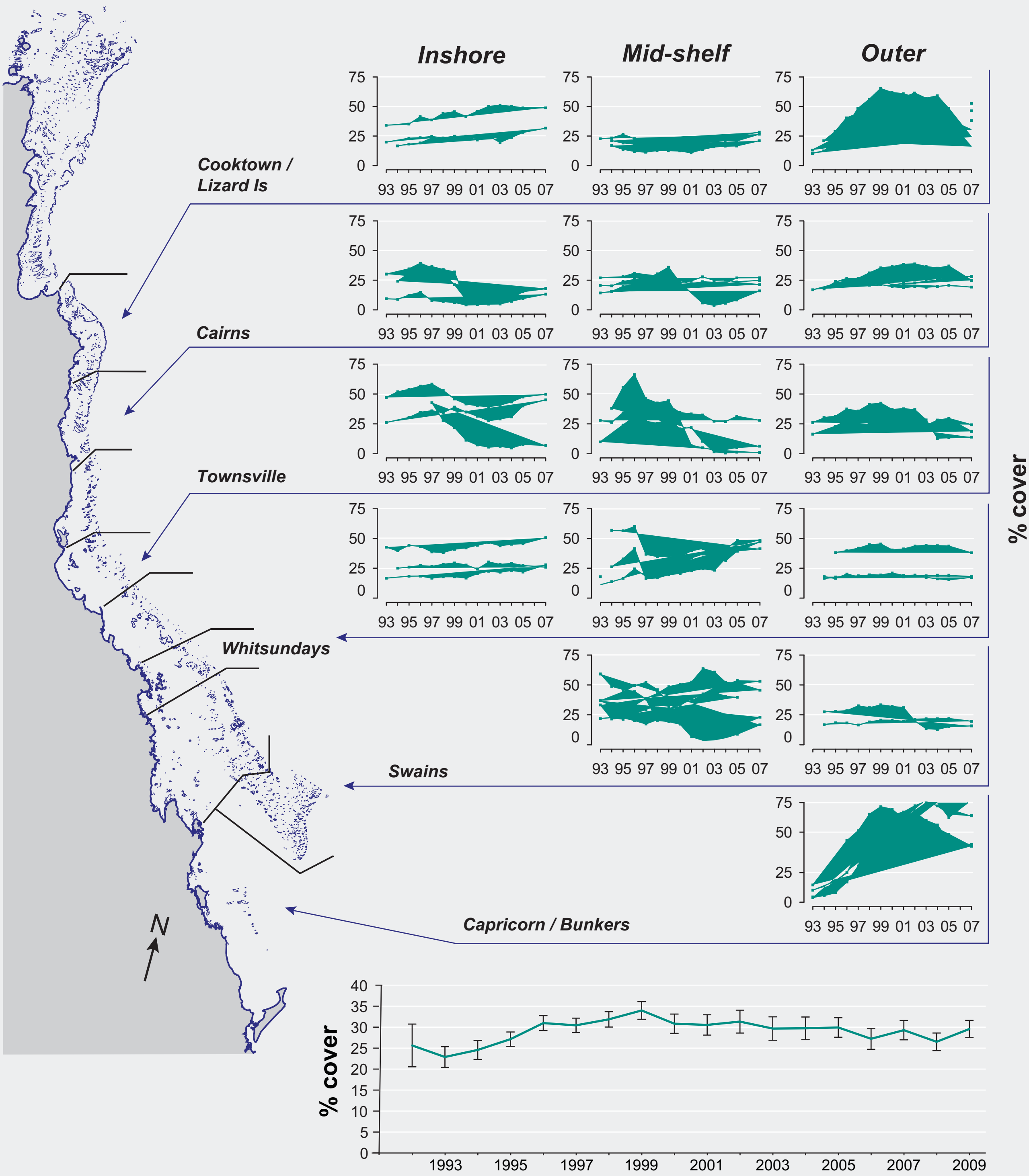


Figure 2.5 | **Hard coral cover, Great Barrier Reef, 1993-2007 as measured during video transects[22]**

Graphs on the right show coral cover through time for individual reefs, grouped by latitude and cross-shelf position. Each line represents the percentage of coral cover observed on permanent transect lines on the north-east corner of an individual reef. The percentage of a reef covered in hard coral changes over time, with individual reefs showing a wide range of patterns, including dramatic declines and increases. The single graph on the bottom shows the overall trend, combining all the data. On a Reef-wide scale, there is no clear pattern of change over the 16 years of this monitoring program, with an average annual change of +0.24%.

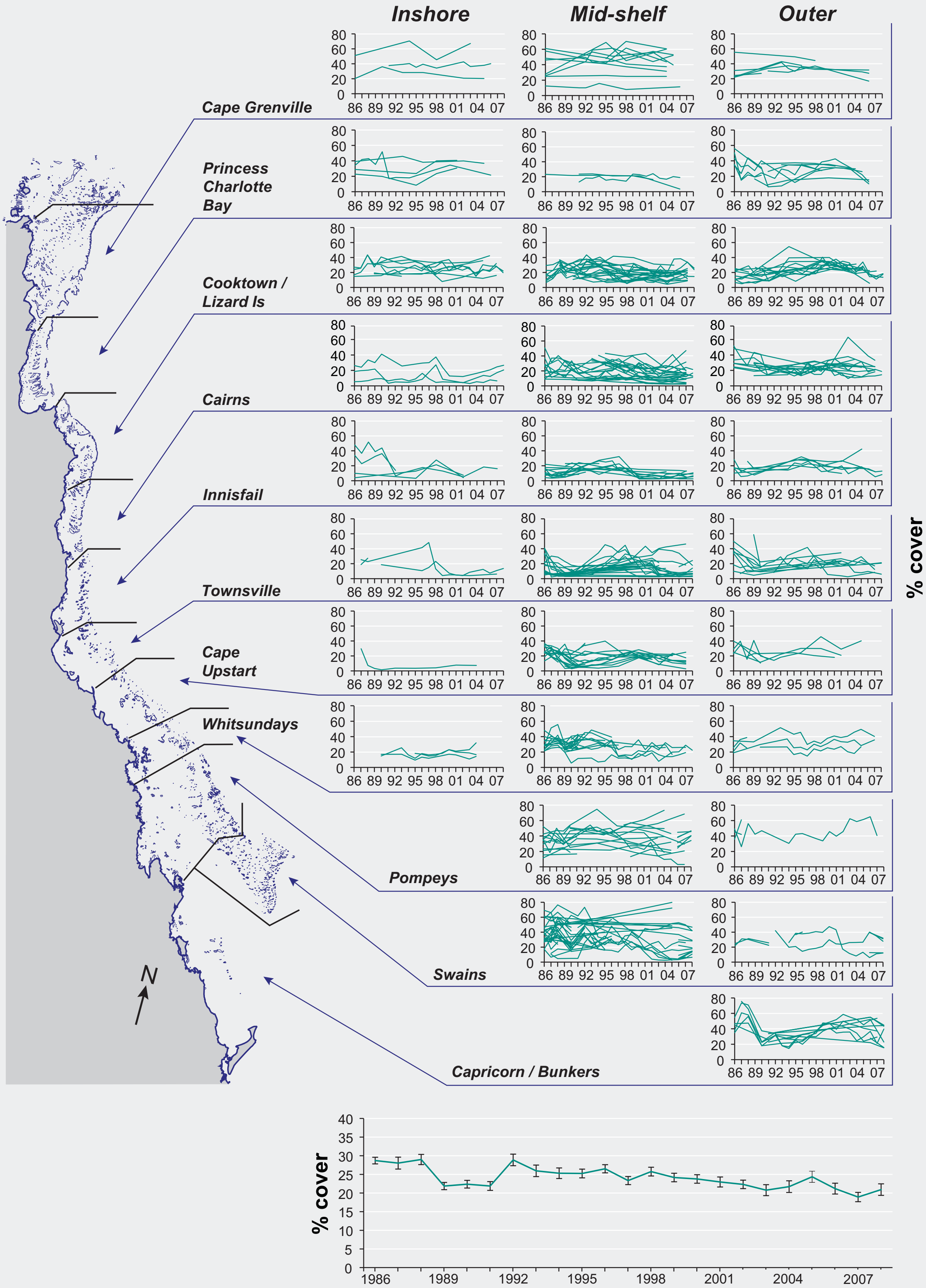


Figure 2.6 | **Hard coral cover, Great Barrier Reef, 1986-2008 as measured using manta tow surveys[22]**

Graphs on the right show coral cover through time for individual reefs. Each line represents the percentage of coral cover observed using manta tow surveys of the perimeter of the reef. As with the video transects, individual reefs show a wide range of changes, including numerous large increases and decreases. The single graph on the bottom shows the overall trend, combining all the data. On a Reef-wide scale, coral cover has declined over the 22 years of this monitoring program, amounting to an average annual change of -0.29%.

Other analyses suggest there may have been significant declines in coral cover prior to the implementation of systematic long-term monitoring. A "meta-analysis" of compiled data from a wide range of disparate earlier studies has suggested that coral cover may have declined by as much as 20 per cent over 40 years.[19] However, this analysis depends on early studies which were not intended to systematically represent the range of conditions across the entire Great Barrier Reef.

There is particular concern about the status of inshore coral reefs in regions most affected by human activity. For example, comparisons of inshore reefs in the Wet Tropics, with inshore reefs north of Princess Charlotte Bay, suggest that the increased runoff from human activities in the Wet Tropics has led to declines in corals and replacement by algae (figure. 2.7).

2.2.3 Seabed

Seaward from the coastal zone, much of the Great Barrier Reef is devoid of reefs. This area is referred to as the 'lagoon' (not to be confused with the lagoons of individual reefs). The absence of reefs in this area is partly due to geological history and partly due to water depth (20-40m) which results in low light levels on the lagoon floor. It is also

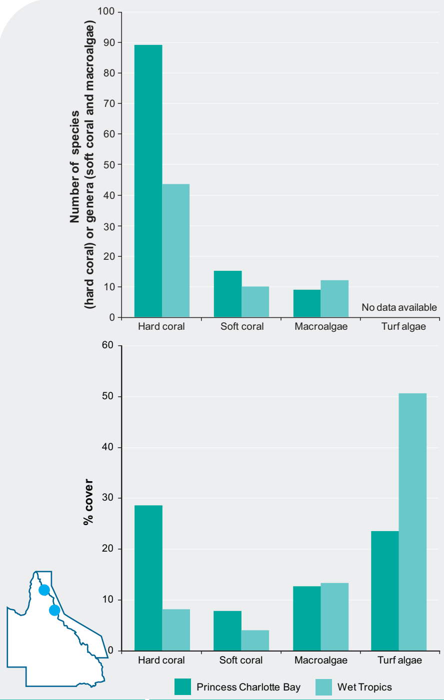


Figure 2.7 Comparison of corals and algae in Princess Charlotte Bay and the Wet Tropics[23]

The richness of coral species and the amount of coral cover is greater in Princess Charlotte Bay compared to the Wet Tropics. The reverse is true for algae. The water quality at the Wet Tropics study sites is significantly worse, with three times as much suspended sediment and twice as much nitrate, particulate nitrogen and particulate phosphorous.

Inshore coral reefs near developed areas have been affected by declining water quality.

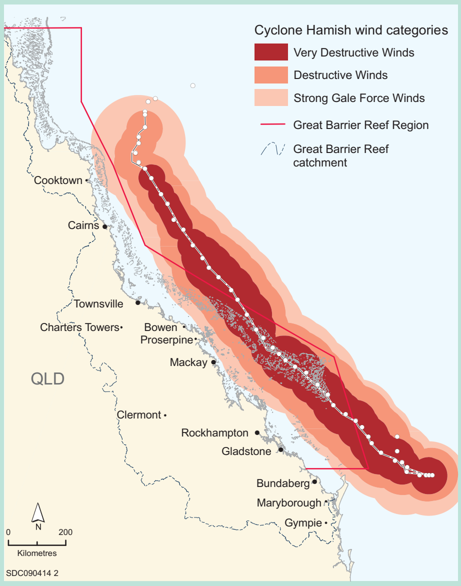
Impacts associated with cyclone Hamish, March 2009

The current status of coral reef habitats in much of the southern Great Barrier Reef was affected dramatically by the impacts of cyclone Hamish, a category five cyclone which tracked down the Region in March 2009.

Although quantitative surveys are still occurring, there is clear evidence that heavy wave action had recently damaged corals, other benthic organisms and the reef framework. Damage was highly variable around each reef and ranged from catastrophic to barely detectable, depending on the orientation of the habitat to prevailing swells. All decreases in coral cover were at least in part caused by the cyclone.

There was a relatively high occurrence of 'white syndrome' and 'brown band' coral disease on a number of inner and mid shelf reefs. The significance of these increases is uncertain but may indicate that 2008/09 was a particularly stressful wet season for corals with high sea surface temperatures, major flood events and intense storm activity.

This damage will have a strong influence on the overall long-term trends of coral reef habitats, as will the extent and rate of recovery from that damage in coming years. *(from Australian Institute of Marine Science)*



Soft seabed habitats support more than 5000 species but are not well understood.

Figure 2.8 | The lagoon floor of the Great Barrier Reef[24]

Examples of the diverse communities found in the sandy and muddy seabeds of the Great Barrier Reef.

Little is known of the status of the Halimeda banks that occur in the northern Great Barrier Reef.

due to the periodic influx of river water during wet season floods.

Lagoon floor The lagoon floor supports a great diversity of life within soft-bottom communities (figure 2.8). These communities are poorly studied and even some common organisms – sea-pens, crinoids, crustaceans, molluscs, and a few fish – are as yet unknown to science. The bioregions of the lagoon floor have been mapped (figure 2.3) and, for the first time, there is now information on the taxonomic variety within shallow soft seabed habitats, with a recent large-scale study recording 5300 species.[25] Bottom trawling has occurred throughout large areas of the lagoon for several decades and damage to some of the more sensitive lagoon communities may have occurred as a result. However, large areas of this habitat are now protected[7 24] after rezoning in 2004.

There is little information about the extent or condition of shoals in the Great Barrier Reef.

Shoals The Great Barrier Reef lagoon also has extensive areas of shoals (figure 2.9), some of which are continental rock, others are reefs that failed to keep pace with the rate of sea level rise after the last glacial interval. The extent or condition of these shoals has not been extensively investigated, but studies are currently underway to determine the types of shoals and the effectiveness of zoning for protecting groups of fish species on shoals. Increasing sophistication in marine navigation equipment has probably increased targeted fishing pressure on shoals, especially on those close to urban centres.

Halimeda banks Large areas of the far northern Great Barrier Reef, inshore of the Ribbon Reefs, are dominated by the calcareous green alga *Halimeda*. These form banks typically up to 20m thick on a seafloor that is around 40m deep.[26] These habitats are poorly studied and little is known of any trends in this habitat.

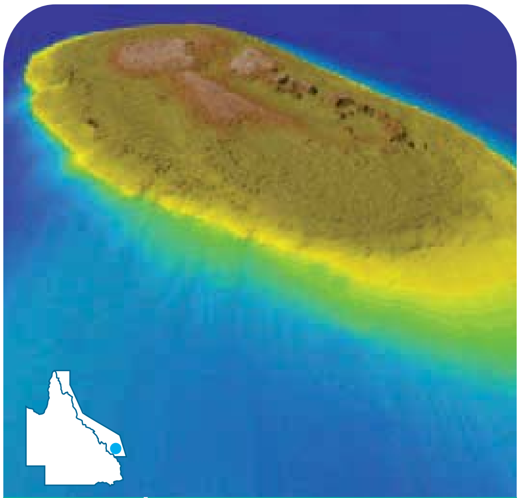


Figure 2.9 | Example of a shoal in the Great Barrier Reef

This multibeam bathymetric image shows that shoals provide structure and shelter in an otherwise soft and flat seabed environment. This shoal, located offshore from Gladstone, is about 2.8km long and has a maximum height above the surrounding seafloor of about 15 - 20m. The changes in colour depict changes in elevation. (Image courtesy T. Stieglitz, James Cook University)

Dwarf minke whales inhabit the open waters of the Ribbon Reefs, near Lizard Island, from May to September.

Many pelagic species depend on open waters but little is known about the condition of these habitats.

Continental slope The continental slope is a complex area composed of relic reefs, landslides, canyons and plateaux.[27 28] It comprises about 15 per cent of the Great Barrier Reef Region. There has been little investigation of this remote habitat or the deep water seabed habitats beyond. These habitats are believed to be essentially undisturbed and hence likely to be in good condition.

2.2.4 Open waters

Open water is, of course, what connects all marine habitats. Within the Great Barrier Reef, open waters extend from the coast to beyond the continental shelf. The physical and chemical properties of Great Barrier Reef open waters (especially currents, temperature and acidity) are reported in Sections 3.2 and 3.3. As habitats in their own right, open water contains pelagic fish (e.g. marlin and mackerel), whales and dolphins, most plankton and a vast array of microbes. On a seasonal basis, plankton includes the larvae of the majority of marine species. Open water is thus the key to connectivity, a critical aspect of the ecology of the whole Great Barrier Reef ecosystem (refer Section 3.4.9).

2.3 Current state and trends of populations of species and groups of species

2.3.1 Plants

The Great Barrier Reef ecosystem has a range of marine plants: mangroves, seagrasses, macroalgae and benthic microalgae. All marine plants are protected under Queensland legislation.

Mangroves Of the 39 mangrove species on the Great Barrier Reef (half of the world's total) the highest biodiversity is found in the far north (figure 2.10). Mangroves are maintaining their biodiversity and, in most places, their abundance (refer figure 5.19) on the Great Barrier Reef, in stark contrast to most of the rest of the world where they have been cleared especially for aquaculture and fuel.[11 29]

Seagrasses World-wide, the Great Barrier Reef is one of the most species rich areas for seagrass (figure 2.11). Some 30 seagrass species occur in Australian waters, half of which are found within the Great Barrier Reef – in estuaries, shallow coastal waters, in the lagoon and sometimes in association with coral reefs. Seagrass meadows are

The Great Barrier Reef continues to support 39 mangrove species, at least 15 species of seagrass and a wide range of marine algal species, including over 600 species of macroalgae.

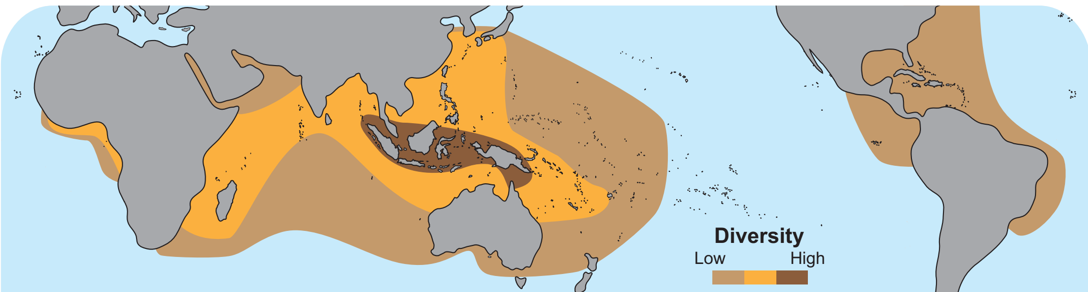


Figure 2.10 Global distribution and diversity of mangrove species[30]

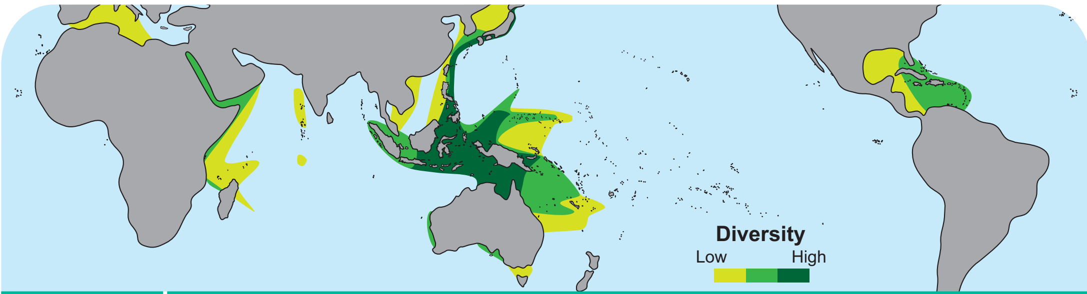


Figure 2.11 Global distribution and diversity of seagrass species[30]

maintaining their species composition and abundance[31] (Section 2.2.1). Observations suggest that there have been shifts in species composition in some seagrass beds, but do not indicate any Reef-wide changes.[32]

Table 2.4 Marine macroalgae classified as 'Vulnerable' and 'Vulnerable with a narrow range' in the Great Barrier Reef[35]

Vulnerable	Vulnerable with a narrow range
Avrainvillea ridleyi	*Cladophora aokii*
Cladophorella calcicola	*Rhipiliopsis echinocaulis*
Halimeda magnidisca	*Chondria rainfordii*
Rhizoclonium capillare	*Gelidiopsis scoparia*
Dictyopteris crassinervia	*Gelidium crinale var perpusillum*
Dictyota bifurca	*Gracilaria purpurascens*
Mesopora schmidtii	*Gracilaria rhodotricha*
Padina tetrastromatica	*Mesophyllum mesomorphum*
Eucheuma sonderi	*Neogoniolithon laccadavicum*
Balliella grandis	*Sebdenia ceylanica*
Gymnophycus hapsiphorus	
Rhipidothamnion secundum	
Seirospora orientalis	
Amphiroa crassa	
Dudresnaya capricornia	
Cryptonemia caliculata	
Halymenia lacerata	
Thamnoclonium tissotii	
Hypnea rugulosa	
Bostrychia binderi	
Laurencia moretonensis	
Laurencia pinnatifida	
Melanamansia daemelii	
Polysiphonia opaca	
Gelidiopsis acrocarpa	
Dicranemarosaliae	

Macroalgae Macroalgae are a diverse group with over 600 species occurring on the Great Barrier Reef[33]. Algal communities are highly variable, with marked differences in species composition and abundance from north to south, from inshore to offshore areas across the continental shelf, and between habitats within reefs. In addition to this spatial variability, many reef macroalgae are highly seasonal. Data from ecological studies of benthic communities of Great Barrier Reef coral reefs show that macroalgae of some form (including turfs, fleshy macroalgae and crustose algae) are widespread and abundant on most reefs, covering between 30 to 80 per cent of the reef substrate.[34] There is little information on the trends in macroalgae populations; however, the conservation status of 36 species of macroalgae is of concern (table 2.4).[35]

Benthic microalgae Benthic microalgae are microscopic plants which grow on both hard bottoms and sandy or muddy sediments. These algae play important roles in primary production and nutrient dynamics in the Great Barrier Reef ecosystem. The abundance and productivity of benthic microalgae in the sediments of coral reefs and the deeper inter-reefal areas has been identified[36] and mapped[37] in some areas of the Great Barrier Reef. The biomass of benthic microalgae is typically several orders of magnitude higher than that of the integrated water column microalgae (phytoplankton).[36] There is little information about trends in the condition of this group of species.

2.3.2 Corals

Scleractinian or hard corals are the signature group of the Great Barrier Reef. Some 411 species have been recorded.[38] This biodiversity is exceeded only by that of the Coral Triangle to the north of Australia (figure 2.12). The diversity of soft corals

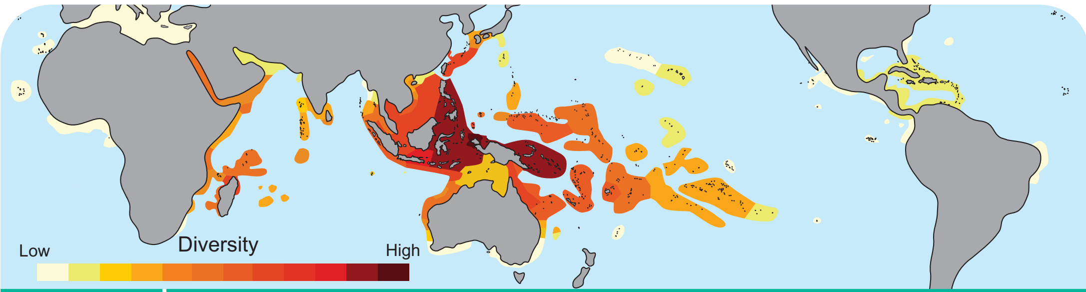


Figure 2.12 | **Global distribution and diversity of hard coral species**

Global hard coral species richness, shading indicates numbers of species. The Coral Triangle (shown in dark red) is the centre of marine biodiversity. (Courtesy of J.E.N. Veron)

There over 400 species of hard corals, with localised declines in coral cover of some species.

is unknown at species level but there is estimated to be at least 150 species of soft corals, sea fans and sea pens.[39]

The number of species of both hard and soft corals varies along and across the Great Barrier Reef (figure 2.13). Even within a single reef there can be great diversity, with up to 120 species of hard coral at one site.[40] There are fewer species of both hard and soft coral inshore adjacent to developed areas.[41] Generally, the number and variety of corals increases with distance from river mouths, showing the important role that water quality plays in coral health.[42]

Hard corals have been extensively damaged by outbreaks of crown-of-thorns starfish (a natural predator) at least since the 1960s. Since the 1980s, corals (particularly hard corals) have been affected by temperature-induced mass bleaching events (where the symbiotic relationship between the coral and its microscopic algae is disrupted and, depending on the severity of the stress, may result in coral mortality). In future, these events are likely to become more frequent and more severe and, increasingly, hard corals will be exposed to the damaging effects of ocean acidification. This will have serious consequences for all reef corals and the habitats they form (refer Section 5.2).

There is little information about the condition of soft corals, sea pens and sea fans.

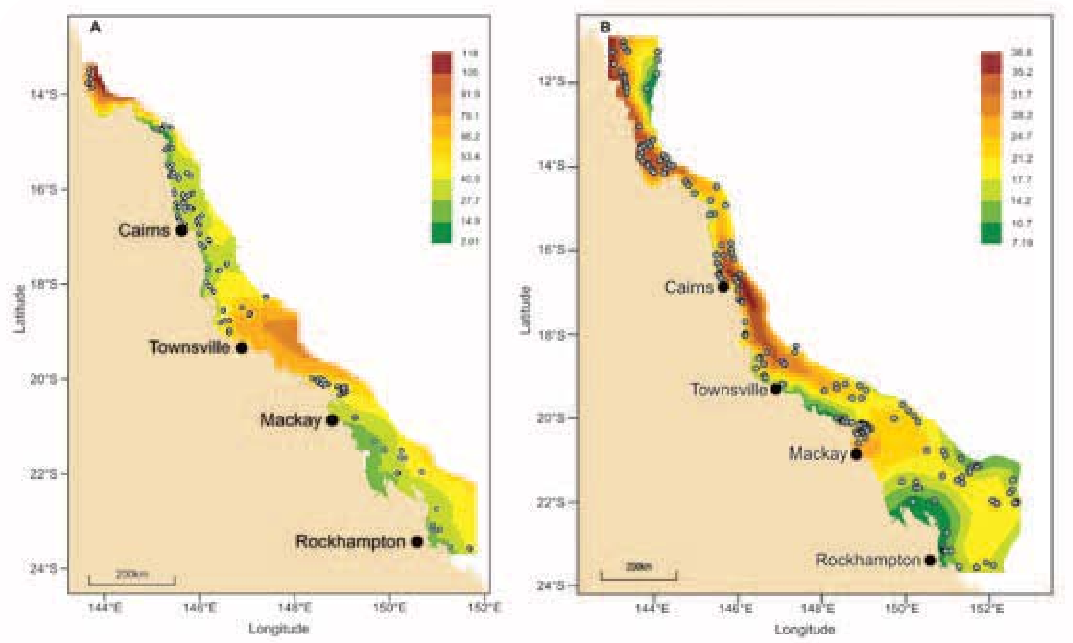


Figure 2.13 | **Hard and soft coral species richness in the Great Barrier Reef**

The number of species of both hard (A) and soft (B) coral varies across the Great Barrier Reef and is reduced in some areas close to the coast. In this modelled depiction of diversity, brown shows higher and green lower species richness. Dots are sampling points. (Images courtesy of the ATLAS)

The amount of coral cover on an individual reef varies from year to year (figures 2.5 and 2.6), but tends to be reduced in areas with reduced water quality (figure 2.7), as is species richness.

All species of the Classes Anthozoa and Hydrozoa (i.e. corals (hard, soft and black), anemones, zoanthids, seafans, corallimorpharians, hydroids and fire corals) are protected under Queensland and Great Barrier Reef Marine Park legislation.

2.3.3 Other invertebrates

Thousands of species of invertebrates (animals without backbones) have been recorded in the Great Barrier Reef and it is likely many more are yet to be discovered.[25] This biodiversity is nationally and internationally significant, with an estimated 30 per cent of Australia's sponge species and more than 10 per cent of the world's echinoderms (starfish, sea urchins and sea cucumbers) found there.[6] With such a vast number of species and only limited research being undertaken, there is insufficient information to determine whether any species are threatened.[43]

Little is known about most non-commercial invertebrate species.

Some crustaceans, such as prawns and crabs, are important in Great Barrier Reef fisheries. Other invertebrates such as trochus, pearl oysters and sea cucumber have been harvested at various times. The status of most species appears to be stable (e.g. mud and blue swimmer crabs). Over the last century there has been extensive harvesting of sea cucumbers (figure 2.14). One species, the black teatfish, has declined drastically since the start of the twentieth century and the fishery for this species was closed in 1999. The pearl oyster has also declined through over harvesting in the late nineteenth and first half of the twentieth centuries.[44]

Little is known about the status of plankton or microbes on the Great Barrier Reef.

Historically, many thousands of tonnes of sea cucumbers were harvested on the Great Barrier Reef, just as in the Torres Strait pictured above. (Photo from Saville-Kent W., 1893, 'The Great Barrier Reef')

Some invertebrate species have been protected (e.g. tridacnid clams, helmet shell, triton shell) because of concerns about localised depletion.

Other invertebrate species are now considered pests (e.g. crown-of-thorns starfish) at some locations because of explosions in their numbers from time to time. Anthropogenic impacts are thought to exacerbate natural population fluctuations (Section 3.5.2).

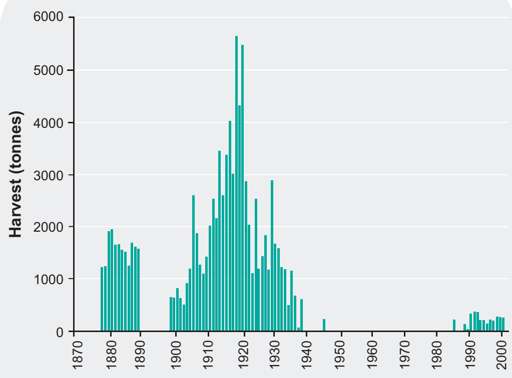


Figure 2.14 Estimated historic catch of sea cucumber in the Great Barrier Reef and adjacent areas[45]

Sea cucumbers were extensively harvested in the early twentieth century in the Great Barrier Reef Region. The harvest of sea cucumbers is measured as tonnes of gutted weight.

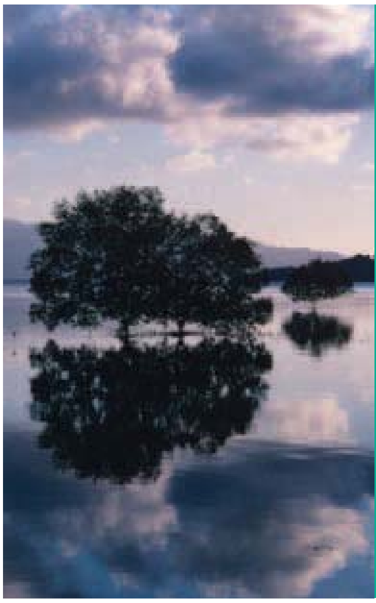
2.3.4 Plankton and microbes

Although the vast array of plankton and microbe taxa plays a vital role in the ecosystem as the foundation of the food web and in many ecological processes, little is known about the status of plankton or microbe species on the Great Barrier Reef. There is little evidence of changes in the biodiversity of plankton and microbes.

2.3.5 Fish

Over 1600 fish species of fish occur on the Great Barrier Reef; the number of reef-associated fish alone being 1468.[46] Fish include sharks, rays and skates.

Bony fish Only a small proportion of non-commercial bony fish species are monitored. The diversity and abundance of most groups of coral reef fishes varies both latitudinally and across the continental shelf [46] (figure 2.15), although patterns are less well-defined than for corals. For most species that are monitored, the populations



Traditional Owner tells of fish in different seasons

Russell Butler of the **Bandjin People** in the Hinchinbrook area, links events in the natural world to the cycles of various fish:

> *"When the big white ti tree blossoms in mid-winter that is the smell that goes through the bush and we know the mullet will be fat and running. Mullet are good for your blood and heart. The catfish will be fat at this time. Black bream will be up the creek. In September we smell the cocky apple and that indicates there are barra(mundi) in the mouth of the rivers and they are fat…if they sit in the rivers too long they become more vulnerable. We follow the cycle of the barramundi as it moves between the river system and the ocean and we know where it is in its life cycle and when it is best to catch them."*

appear stable[22] (figure 2.16). Exceptions may include groups of species that are influenced by decreases in predator numbers[47] and groups of species influenced by the effects of declining water quality.[48]

About 55 to 60 species of fish, such as coral trout, mackerel and barramundi, are targeted by commercial and recreational fishing. This has resulted in fewer fish in the regularly fished areas when compared to zones closed to fishing (figures 2.17 and 2.18). Information on the state and trends of target fish populations in the Great Barrier Reef Marine Park is very limited, with formal stock assessments for only a few species (e.g. Spanish mackerel and snapper).

Some fish, such as humphead Maori wrasse, Queensland groper, and the other larger (greater than 100cm) *Epinephelus* species (groupers) are protected under Great Barrier Reef Marine Park and Queensland legislation because of their iconic status.

There are no records of extinction of bony fish species in the Great Barrier Reef although there are concerns about reduced populations for some target species (e.g. grey mackerel and garfish).[51]

Coral cod can live for more than 30 years and are one of the many important fish species on the Great Barrier Reef.

Of the more than 1600 fish species, only a few are known to have locally depleted populations.

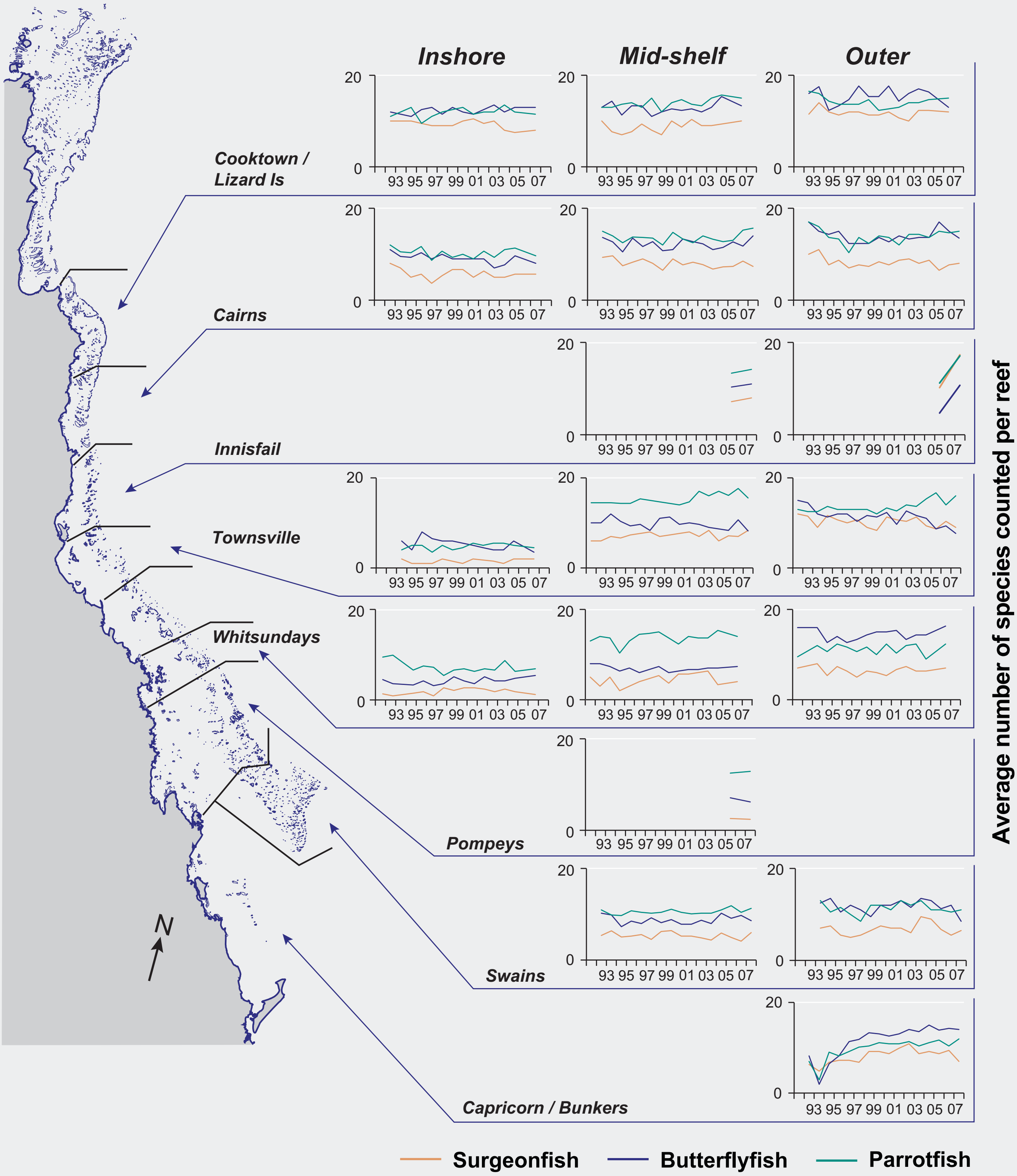


Figure 2.15 Species richness of some coral reef fish groups on the Great Barrier Reef, 1991-2007

Surgeonfish, butterflyfish and parrotfish are examples of how reef fish species richness changes in different areas of the Great Barrier Reef over time. (Data from AIMS Long-Term Monitoring Program)

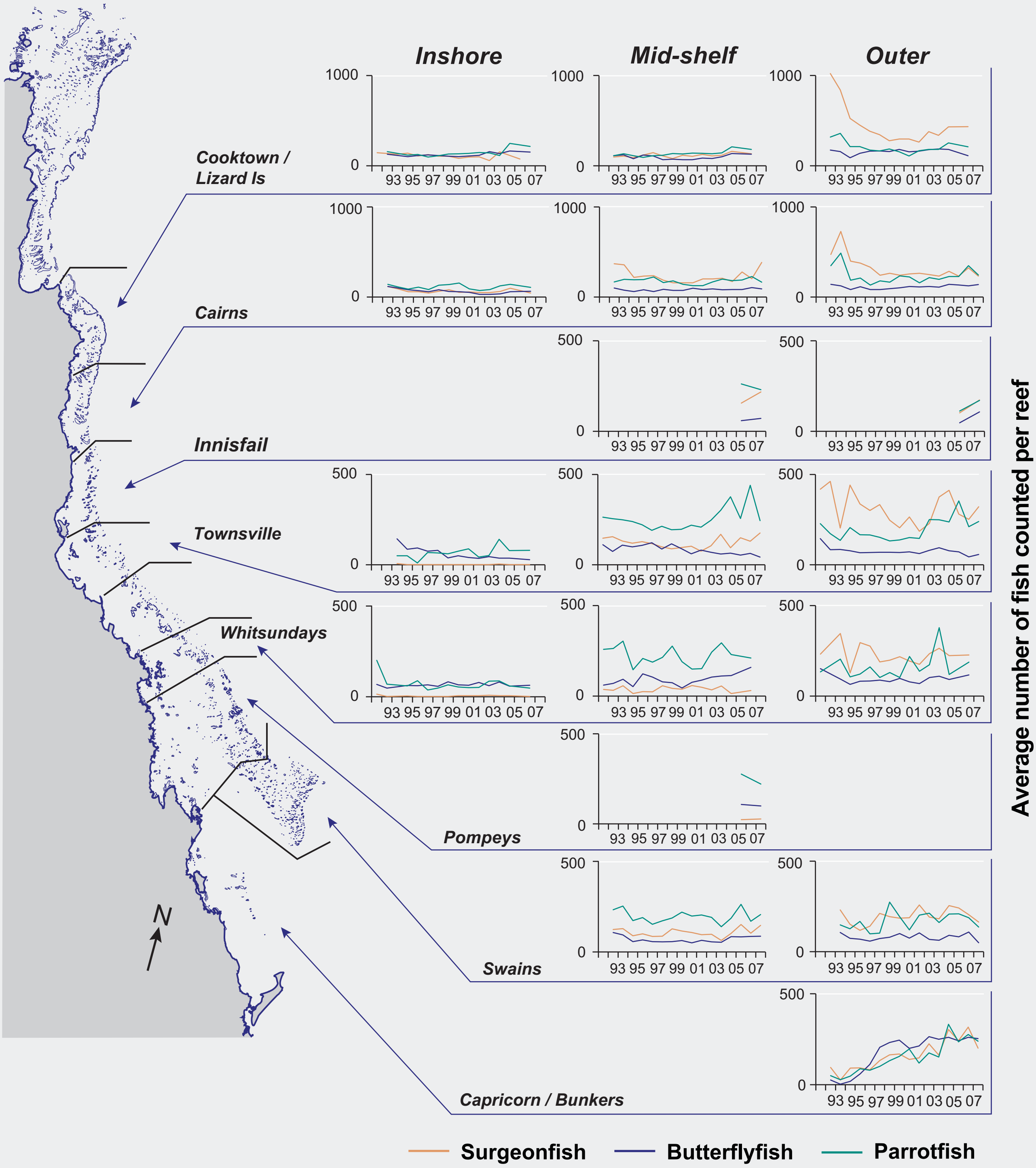


Figure 2.16 Abundance of some coral reef fishes on the Great Barrier Reef, 1991-2007

Surgeonfish, butterflyfish and parrotfish are examples of how the number of reef fish changes in different areas of the Great Barrier Reef over time. (Data from AIMS Long-Term Monitoring Program)

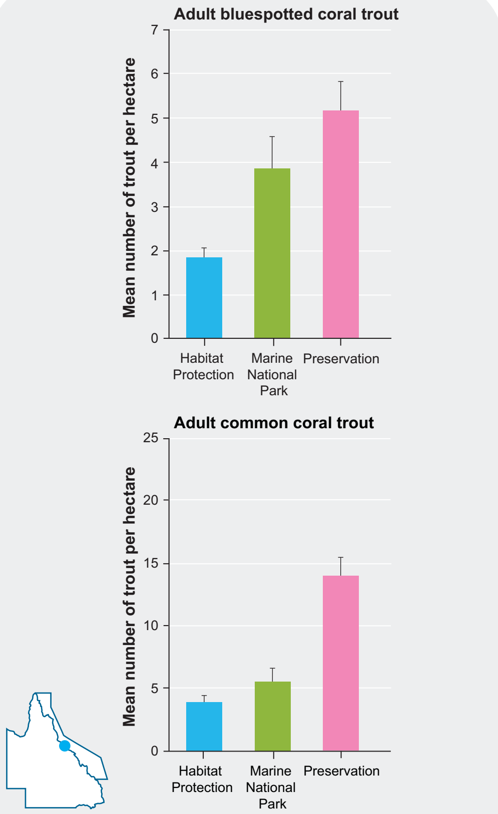


Figure 2.17 Coral trout population densities across zones[49]

The density of coral trout in the Habitat Protection Zone (open to fishing) is much reduced compared to that in the Marine National Park and Preservation Zones that are closed to fishing. With regard to the two zones that are closed to fishing, the recorded difference in coral trout density is likely to be the result of illegal activity in the Marine National Park Zone. All study reefs were in the Townsville region and were surveyed in 2008. The black bars indicate the standard error around the mean.

Cartilaginous fish - Sharks and rays There are 182 shark species, 125 ray species and 15 chimaerid species in Australian waters, the greatest biodiversity of any continental area.[52] Sharks have undergone very serious declines in most parts of the world, so-much-so that Australia has become one of their few refuges. While there is little detailed information about populations for most of the 134 species of sharks and rays recorded on the Great

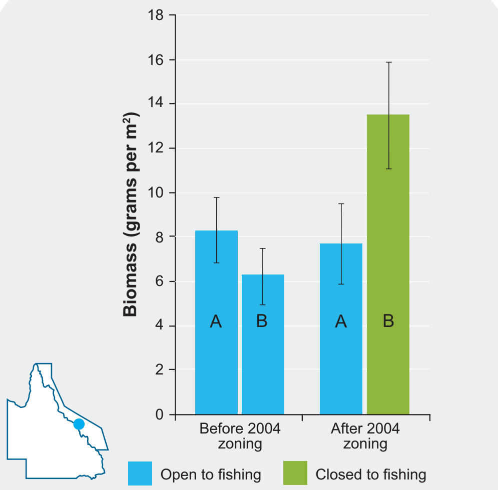


Figure 2.18 Biomass of coral trout[50]

Coral trout tend to be larger in places where fishing pressure has been removed. This leads to a higher reproductive output. Surveys were conducted in 2003-2004 and 2006 at sites around the Whitsunday Islands. The two sets of bars represent the same sites before and after 2004 zoning. The black bars indicate the standard error around the mean.

Success in restoring reef fish populations

Garry Russ, from the **ARC Centre of Excellence for Coral Reef Studies** in Townsville, leads a study surveying 56 reefs over more than 1000km of the Great Barrier Reef, investigating recovery in zones closed to fishing. He explains the positive results they have found since 2004:

"Coral trout numbers rebounded on reefs which had been closed to fishing for as little as 1.5 to 2 years. … We were very agreeably surprised at the speed at which coral trout populations recovered – and also the sheer scale and consistency of the response. … Our findings show that large scale reserve networks, set up to protect biodiversity and ecosystems, can produce rapid positive responses for harvested species."

Barrier Reef[53], some species are known to have declined significantly (figures 2.19 and 2.20). Sharks and rays have come under serious pressure on the Great Barrier Reef as a result of some fishing activities (including targeted fishing, illegal fishing and as bycatch) and to a lesser extent the shark control program (designed to provide swimmer protection at popular beaches).[54]

A recent risk assessment of northern Australian sharks and rays found that 25 species of sharks and rays were at relatively high risk in the East Coast Inshore Finfish Fishery and were 'least likely to be sustainable' when targeted or caught as bycatch.[55] In late 2008 the Queensland Government approved a number of changes to fisheries management arrangements to be implemented between March and July 2009. The changes limit the recreational and commercial shark catch as well as protecting some shark species more at risk by making them no-take and protecting some critical habitat areas.

There are six listed threatened shark species in the Great Barrier Reef, including the green sawfish[57] and the whale shark (table 2.3). Two further species (the dwarf and narrow sawfish) are listed as no-take under Queensland fisheries legislation. Pressures on shark populations are more serious than on other fishes because they are slower breeders and being top predators, are less abundant than prey species.

There is concern about declines in populations of some of the 134 shark and ray species.

Early last century massive sawfish and other sharks were often caught on the Great Barrier Reef, such as this one at the Mulgrave River. Sawfish are now rarely seen (Photo courtesy of the State Library of Queensland)

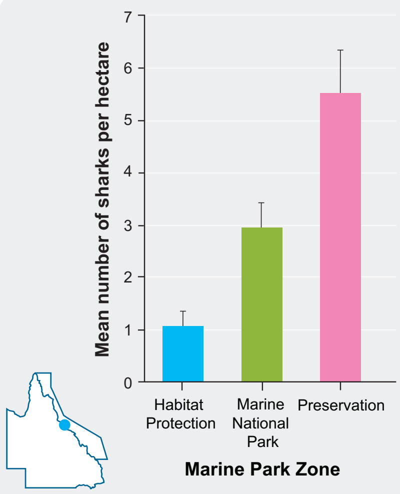


Figure 2.19 **Reef shark densities across zones[49]**

Fishing is seriously affecting reef shark populations surveyed in this study. Surveys at mid-shelf reefs in the Townsville region show that shark densities (grey reef, whitetip reef, silvertip and blacktip reef sharks) are about twice as high in reefs closed to fishing (Marine National Park Zone) and four times as high in no entry reefs (Preservation Zone) compared to reefs open to fishing other than trawling (Habitat Protection Zone). The black bars indicate the standard error around the mean.

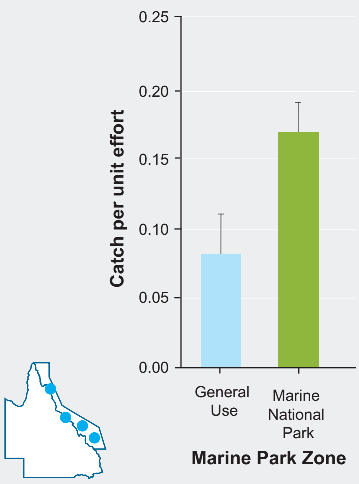


Figure 2.20 **Reef shark population densities across zones[56]**

In the Effects of Line Fishing research project, experimental fishing was undertaken in selected Marine National Park Zones that were otherwise closed to fishing. The significantly higher catch per unit effort in this zone when compared to fishing in the General Use Zone (open to all fishing) is an indication of the increased density of shark populations in areas closed to fishing. Catch per unit effort is measured as the number of sharks caught per hour. The black bars indicate the standard error around the mean.

Six of the world's seven marine turtle species occur in the Great Barrier Reef, all are threatened species.

2.3.6 Marine reptiles

Turtles Six of the world's seven species of marine turtle occur on the Great Barrier Reef and the Region has globally significant nesting areas for four of them.[6] All six species are classified as threatened (table 2.3) as a result of pressures both from within the Great Barrier Reef Region and elsewhere.

Current cumulative pressures on marine turtles in the Great Barrier Reef include incidental capture in some fishing gear (e.g. nets, crab pots), boat strike, ingestion of and entanglement in marine debris, illegal hunting, unsustainable traditional hunting, coastal development impacting nesting beaches and hatching success, and disease.[58 59] Future loss of habitat for nesting sites from predicted sea level rise poses an extreme risk to nesting species.[59]

The loggerhead, flatback and green turtle nesting populations appear to have stabilised or are now increasing.

Although the number of breeding green turtles fluctuates annually by an order of magnitude concurrent to El Niño weather events[61], recent studies indicate that the southern Great Barrier Reef green turtle genetic breeding stock is increasing[62] after commercial harvest in the first half of the 1900s.[60] The northern Great Barrier Reef green turtle genetic breeding stock appeared to be increasing through the 1970s and then levelled off in the 1990s.[62] Recently, concerns for this stock have been raised because of poor nesting and hatching success at Raine Island[63] and suspected unsustainable harvesting of adult females throughout their range.

Harvested turtles on Mon Repos Beach, 1930s

Marine turtles were extensively harvested in the Great Barrier Reef in the late nineteenth century and early twentieth century [60], just as they were in Mon Repos which lies just south of the Great Barrier Reef. (Photo courtesy of the State Library of Queensland)

Trends of the number of nesting flatback turtles from the eastern Australian genetic stock appear stable over the past three decades, although information from the early 1900s suggest a substantial population decline occurred.[64]

Numbers of nesting hawksbill turtles have declined at Milman Island in the far north of the Great Barrier Reef by three per cent per year since 1991[65] and loggerhead turtles have declined at the Wreck Island nesting site (in the Capricorn Bunker Group) by 86 per cent from 1977 to 2000 (figure 2.21).[66] In 2005, less than 100 loggerhead turtles nested at Wreck Island.

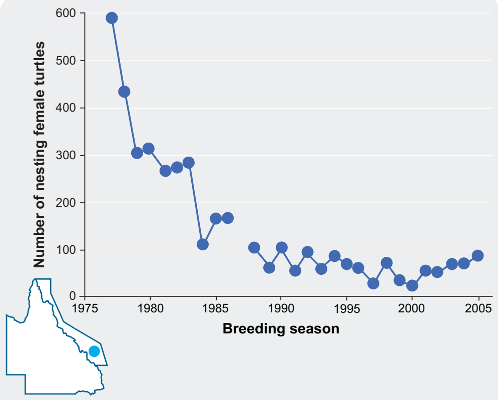


Figure 2.21 Loggerhead turtle nesting at Wreck Island, 1965-2005[67]

Wreck Island in the southern Great Barrier Reef is one of the main breeding sites for loggerhead turtles. At this site, populations have now stabilised after decades of decline.

The compulsory use of turtle excluder devices in prawn trawl nets since 2001 and targeted fox control programs seems to have helped stop the decline of loggerhead turtles.[68 69] However, a new threat has emerged. For the past 15 years, there has been a reduction in recruitment of loggerhead turtles to inshore coastal waters from the oceanic pelagic habitats of the wider South Pacific Ocean. This is likely to result in a decline in the nesting population within the next two decades unless the overseas mortality factors (mainly entanglement in international longline fisheries gear and ingestion of marine debris) are addressed.[68] Altered lighting along nesting beaches as a result of coastal development is also affecting hatchlings' ability to find the sea.[68]

Sea snakes There are 14 species of sea snake in the Great Barrier Reef and all are protected under national legislation.[70] It is estimated that about 100 000 sea snakes are taken each year during trawling activities in the Queensland east coast trawl fishery.[71] Mortality rates vary, depending on the species and the nature of the trawling activity, but can be as high as 37 per cent.[72] Although the trawl fishery continues to cause significant incidental catch and mortality on sea snakes, some bycatch reduction devices show potential for excluding a high proportion of snakes from trawl nets.[73]

Estuarine crocodiles Estuarine crocodiles occur in most coastal waters of the Great Barrier Reef. Although extensively harvested since European settlement, their numbers in northern Queensland are now recovering after being fully protected under Queensland legislation since 1974. This recovery is limited primarily by the availability of suitable nesting habitat.[74] The potential for interactions with humans will increase both as the crocodile population recovers and as more people move to Great Barrier Reef catchments.

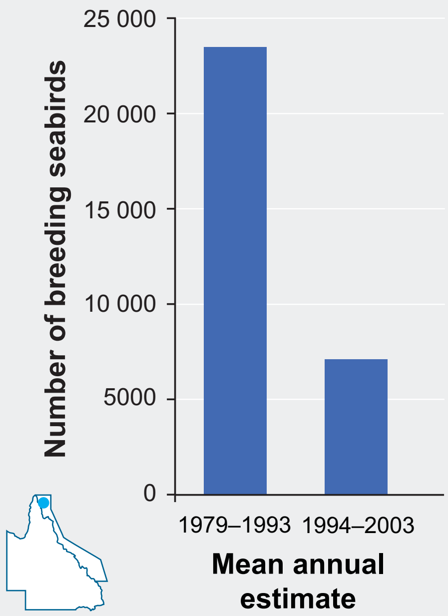


Figure 2.22 **Annual seabird breeding population at Raine Island, 1979-2003**[77]

Long-term monitoring shows serious declines in the total number of seabirds breeding at sites such as Raine Island. Of the 16 species that breed on Raine Island, there was a 95 per cent decline in the nesting population of the common noddy and a nearly 70 per cent decline in lesser frigate birds.

2.3.7 Seabirds

Islands and cays within the Great Barrier Reef Region support breeding populations of 22 seabird species[75], which is about a quarter of Australia's tropical seabird breeding population and up to half the global population for some species.[76] In terms of numbers, variety and conservation significance, the four most important seabird areas in the Great Barrier Reef are Raine Island[77], Michaelmas Cay[78], the cays of the Swain reefs[79] and the islands of the Capricorn Bunker Group.[80] Recently, seabird numbers have declined seriously at these sites. For example, at Raine Island in the far north, the estimated average annual breeding population for the years 1994 to 2003 was 70 per cent lower than for the years 1979 to 1993 (figure 2.22)[77], with no evidence that the birds have moved to other breeding sites in the Great Barrier Reef. One suggested cause of the declines throughout the Great Barrier Reef is poor breeding success linked to changes in the distribution of pelagic fish, the main food source for many species. These fish distributions may be changing because of warmer sea temperatures linked to climate change.[81] The overall condition of the islands they use for breeding, particularly the vegetation, can also affect breeding success.[76]

The Great Barrier Reef is an important seabird breeding area.

There are serious concerns about the status of some of the 14 sea snake species.

Numbers of estuarine crocodiles are recovering following protection of the species.

Twenty-two species of seabirds breed on the Great Barrier Reef with serious declines in some populations.

There is no evidence that populations of any of the eight threatened seabird species (table 2.3) are recovering.

2.3.8 Marine mammals

Populations of two inshore dolphin species are very small and at risk.

Based on available information, more than 30 species of marine mammals (dugongs, whales, dolphins) occur in the Great Barrier Reef.[82] Some species are frequently seen, such as humpback and dwarf minke whales and bottlenose dolphins. Other species, such as killer whales and common dolphins, are known to occur in the Great Barrier Reef but are seldom seen or perhaps seldom recognised. Others have stranded on the adjacent Queensland coast and so are believed to inhabit Great Barrier Reef waters occasionally. One species, Longman's beaked whale, is thought to occur in Queensland from a single skull found on a beach in Mackay. All marine mammals are considered species of conservation concern.

Most whales appear to be maintaining intact populations.

Numbers of dugong have declined drastically along the urban coast.

Whales Populations of most whale species that occur in the Great Barrier Reef are thought to be intact although there is limited monitoring of most. Without the pressure of whaling (which ceased in the early 1960s), humpback whale populations are recovering throughout the world, including the population that migrates each winter to the Great Barrier Reef Region.[83] The population of 'east Australian' humpback whales was as low as 500 animals when whaling ceased. The population in 2008 was estimated to have been more than 10 000 animals[83], which is about half of the estimated pre-whaling population size (figure 7.10).

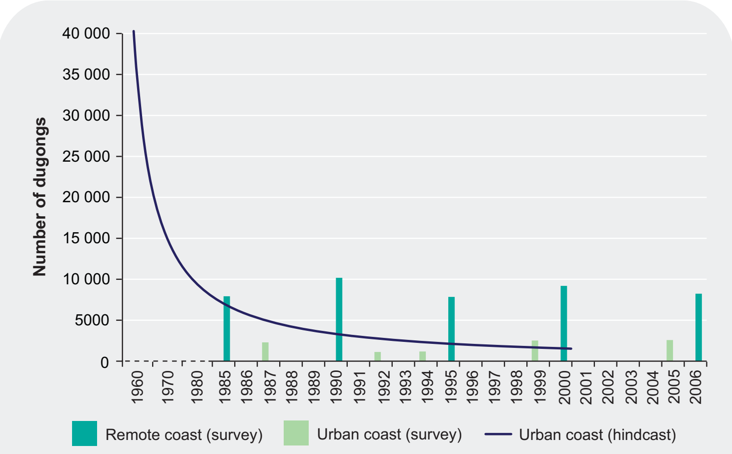


Figure 2.23 | Dugong populations in the Great Barrier Reef[86 87 89]

The number of dugongs along the 'urban coast' of the Great Barrier Reef (from Cooktown south) may have stabilised, but is a tiny fraction of the original population. 'Remote coast' populations (north of Cooktown) have been relatively stable since aerial surveys began in 1985. The hindcast modelling of the 'urban coast' population (dark blue line) was based on the incidental take of dugongs in shark control program nets since the early 1960s, which was used an index of the change in the 'urban coast' dugong population.

Dolphins Although not listed as threatened species in relevant legislation, populations of two inshore marine mammals, the endemic Australian snubfin dolphin and the Indo-Pacific humpback dolphin are at risk[84 85], especially from interactions with large mesh fishing nets and increasing human use of their inshore habitat. There is limited information for any other dolphin species in the Great Barrier Reef.

Dugongs There is serious concern for the threatened dugong. Its population has declined drastically in areas from Cooktown south[86 87], known as the 'urban coast', historically as a result of commercial hunting and incidental bycatch in large mesh (gill) nets, and more recently because of the cumulative pressures of habitat loss, incidental capture in large mesh (gill) nets, boat strikes, illegal hunting (poaching), unsustainable traditional hunting, disease and ingestion of marine debris.

Based on the incidental take of dugongs in shark control program nets since the early 1960s, which was used as an index of the change in the status of the 'urban coast' dugong population between 1962 and 1999, it is estimated that the 'urban coast' dugong population has drastically declined to be about three per cent of its size about 40 years ago, although numbers may now be stabilising at a low level[86 88] (figure 2.23).

There is a greater density and number of dugongs in the remote coast (northern third of the Great Barrier Reef north of Cooktown) and populations appear stable in that area[86 87 89] (figure 2.16). However, estimates of loss from human activity, (principally traditional hunting and incidental capture in large mesh (gill) nets), indicates the potential for a declining population.[90]

Recollections of dugongs

An anecdote from just south of the Great Barrier Reef in 1876 illustrates how large dugong populations once were:

> *"One of the fishermen of Wide Bay told the writer…he had seen a mob which appeared to fill the water with their bodies. He computed this school….to be half a mile wide and from three to four miles long…The writer's boat once anchored in Hervey's Bay, in one of those channels through which the tide passes when running off the flats. For between three and four hours there was a continuous stream of dugong passing while the tide went out, which those in the boat could only liken to the rush of cattle out of a stockyard after a general muster…..some thousands must have gone out with the tide."*
>
> Thorne, E. (1876). Queen of the Colonies.

2.4 Assessment summary - Biodiversity

Section 54(3)(b) of the *Great Barrier Reef Marine Park Act 1975* requires "*…an assessment of the current biodiversity within …*" the Great Barrier Reef Region. This assessment is based on two assessment criteria:

- habitats to support species
- populations of species and groups of species.

2.4.1 Habitats to support species

Assessment component	Summary	Assessment Grade			
		Very good	Good	Poor	Very poor
Islands	About half of the islands are within protected areas; there is limited monitoring on the condition of most islands.		○		
Beaches	In some areas, changes in coastal dynamics and reclaiming of marine areas have altered the beach habitats of the Great Barrier Reef.		○		
Mangroves	The overall area of mangrove forest adjacent to the Great Barrier Reef appears to be generally stable except where there is significant coastal development.		○		
Seagrass meadows	Changes in seagrass communities appear to be mainly due to natural cycles of decline and recovery although influenced by runoff from catchments.		○		
Reefs	Coral reef habitats are likely to be declining, more so in inshore areas, but the trends are difficult to interpret.		○		
Lagoon floor	Soft seabed habitats support more than 5000 species but are not well understood.		?		
Shoals	There is little information about the extent or condition of shoals in the Great Barrier Reef.		?		
Halimeda banks	Little is known of the status of the *Halimeda* banks that occur in the northern Great Barrier Reef but they are believed to be in very good condition.	?			
Continental slope	The continental slope is little studied but believed to be in very good condition.	?			
Open waters	Many species depend on open waters but little is known about the condition of these habitats except that inshore areas are being degraded.		?		

Assessment component	Summary	Very good	Good	Poor	Very poor
Habitats to support species	For most of the Great Barrier Reef, habitats appear to be intact. Some inshore habitats (such as coral reefs) have deteriorated, caused mostly by reduced water quality and rising sea temperatures. This is likely to have affected species that rely on these habitats. Little is known about the soft seabed habitats of the lagoon, open waters or the deep habitats of the continental slope.		○		

GRADING STATEMENTS

Very good - All major habitats are essentially intact and able to support dependent species.

Good - Some habitat loss or alteration has occurred in some areas, but is not causing persistent or substantial effects on populations of dependent species.

Poor - Habitat loss or alteration has occurred in a number of areas and is causing declines in populations of many dependent species.

Very poor - Widespread habitat loss or alteration such that dependent species cannot be adequately supported, causing severe declines in a large number of dependent species.

2.4.2 Populations of species and groups of species

Assessment component	Summary	Very good	Good	Poor	Very poor
Mangroves	The Great Barrier Reef is maintaining strong mangrove biodiversity with local fluctuations, mainly along the developed coast.	●			
Seagrass	The Great Barrier Reef is maintaining seagrass biodiversity with local fluctuations in inshore waters.		●		
Macroalgae	The biodiversity of macroalgae is being maintained but there is little information about its condition.		?		
Benthic microalgae	Benthic microalgae are little studied, but they are believed to be in good condition.	?			
Corals	There are more than 500 species of corals, with localised declines in some hard corals and limited information about soft corals, sea pens and sea fans.		●		
Other invertebrates	Little is known about most non-commercial invertebrate species.	?			
Plankton and microbes	Little is known about the status of plankton or microbes on the Great Barrier Reef.	?			
Bony fish	Of the more than 1600 bony fish species, only a few are known to have locally depleted populations.		?		
Sharks and rays	There is concern about declines in populations of some of the 134 shark and ray species.			?	
Marine turtles	Five of the six species of marine turtle on the Great Barrier Reef have declined; the loggerhead, flatback and green turtle nesting populations appear to have stabilised or are now increasing.			○	
Sea snakes	There are 14 species of sea snake on the Great Barrier Reef and there are serious concerns about the status of some species.			?	
Estuarine crocodiles	Numbers of estuarine crocodiles are recovering following protection of the species.		●		
Seabirds	Twenty-two species of seabird breed on the Great Barrier Reef with serious declines in some populations.			○	
Whales	Most whales appear to be maintaining intact populations. Humpback whales are recovering strongly after being decimated by whaling.		●		
Dolphins	There is limited information about most dolphin populations; but two inshore dolphin species are known to be at risk.		?		

Assessment component	Summary	Very good	Good	Poor	Very poor
Dugongs	Numbers of dugongs have declined drastically along the 'urban coast' but may now be stabilising. The remote coast population does not appear to have changed.			○	
Populations of species and groups of species	Populations of almost all known Great Barrier Reef species or groups of species appear to be intact, but some populations such as dugongs, as well as some species of shark, seabirds and marine turtles, are known to have seriously declined, due mainly to human activities and declining environmental conditions. Many species are yet to be discovered and for many others, very little is known about their status. In time, more populations are likely to decline. Populations of some formally listed threatened species have stabilised but at very low numbers; other potentially threatened species continue to be identified.		◉		

GRADING STATEMENTS

Very good - Available evidence indicates only a few, if any, populations of a species or group of species have declined.

Good - Populations of a number of species have declined significantly.

Poor - Populations of many species have declined significantly.

Very poor - Populations of a large number of species have declined significantly.

2.4.3 Overall summary of biodiversity

The Great Barrier Reef is one of the world's best known and most complex natural systems and it continues to support extensive plant and animal biodiversity. This biodiversity is nationally and internationally important for the continued survival of many species.

The sheer scale of the ecosystem means monitoring has focused on a few key habitats and species or groups of species, generally those that are iconic (such as coral reefs, seabirds), commercially important (such as seagrass meadows, coral trout) or threatened (such as dugongs, marine turtles). There are few long-term monitoring programs established and the baseline from which to make comparisons is different for each group studied.

There is little detailed information about the status and trends of many habitat types within the Great Barrier Reef (for example the lagoon floor, shoals, *Halimeda* banks and the continental slope). However, there is some evidence of a small decline in coral reef habitat over recent decades. This may have already begun to affect species that depend on that habitat.

Populations appear to be intact for the vast majority of species or groups of species in the Great Barrier Reef ecosystem. Latitudinal and cross-shelf biodiversity appears to be being maintained; however inshore species and their habitats adjacent to the developed coast are under more pressure than those both offshore and further north. Populations of a number of ecologically significant species, particularly predators (such as sharks, seabirds) and large herbivores (dugongs), are known to have seriously declined. Declines in species or groups of species have been caused by a range of factors, some of which have been addressed with evidence of recovery of some affected species (e.g. humpback whales, the southern Great Barrier Reef green turtle stock).

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ECOSYSTEM HEALTH

CHAPTER THREE

"It is a thing staggering to the imagination that animals so simple in structure can build a rampart 1260 miles long, many miles wide and not less than 180 feet high."

Sir Maurice Yonge, 1930
Zoologist, Fellow of the Royal Society
and pioneer Great Barrier Reef researcher

"an assessment of the current health of the ecosystem within the Great Barrier Reef Region and of the ecosystem outside that region to the extent that it affects that region..." Section 54(3)(a) of the *Great Barrier Reef Marine Park Act 1975*.

3 ECOSYSTEM HEALTH

3.1 Background

The notion that the word 'health' could be applied to ecosystems as well as organisms arose in the early 1980s, separating the concept of 'healthy' from that of 'pristine'. The concept of ecosystem health is now associated with one of normality: healthy ecosystems are more-or-less unchanged or natural. In the case of marine environments, where there is usually little historic data, an ecosystem can easily be described as healthy or even pristine, when it may in fact be changing, usually for the worse.

In assessing the health of an ecosystem, such as the Great Barrier Reef, it is important to consider that, over time, our concept of what is 'normal' has changed (the baseline has shifted). This assessment of ecosystem health is structured around the main physical, chemical and ecological processes of the Great Barrier Reef ecosystem (figure 3.1). In addition, it examines outbreaks of disease or introduced or pest species as a guide to overall health.

A healthy ecosystem is one where ecological, physical and chemical processes are maintained.

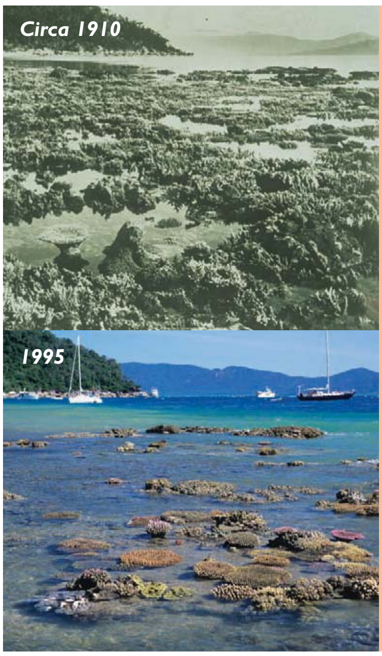
3.2 Current state and trends of physical processes

The components of physical processes include ocean currents, cyclones, freshwater inflows, sedimentation, sea level, sea temperature and light.

3.2.1 Ocean currents

Waves, currents and tides all mix oceanic water, and all have an important effect on marine life. The Great Barrier Reef is part of a massive system of ocean circulation throughout the Pacific Ocean (figure 3.2), which delivers nutrients and larvae from other regions as well as deep water onto the Great Barrier Reef. Ocean currents can be seasonal; the patterns of circulation associated with the dominant 'South East Trades' weather patterns change with the onset of the 'North West Monsoons'. Other currents are transient.

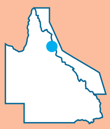
On reaching the Great Barrier Reef, the Southern Equatorial Current divides. A northward-flowing branch circulates around the northern Coral Sea and a southward-flowing branch forms the East



Shifting baselines

It's only natural that someone seeing the Great Barrier Reef today compares it with their own previous experiences. People have a baseline of what they think the Great Barrier Reef was like naturally and therefore how much it has changed.

But today's baseline is not that of Captain James Cook or previous Traditional Owner generations. The changes that have taken place on the Great Barrier Reef in the last 200 years have been profound – but they have been gradual and many we have hardly noticed. An understanding of these shifting baselines, of the changes that most of us have not actually witnessed, is important when assessing the state of the ecosystem and the trends it is following.



The Great Barrier Reef over time
Fitzroy Island, offshore from Cairns, has changed over the years and today's baseline is very different to that of last century.

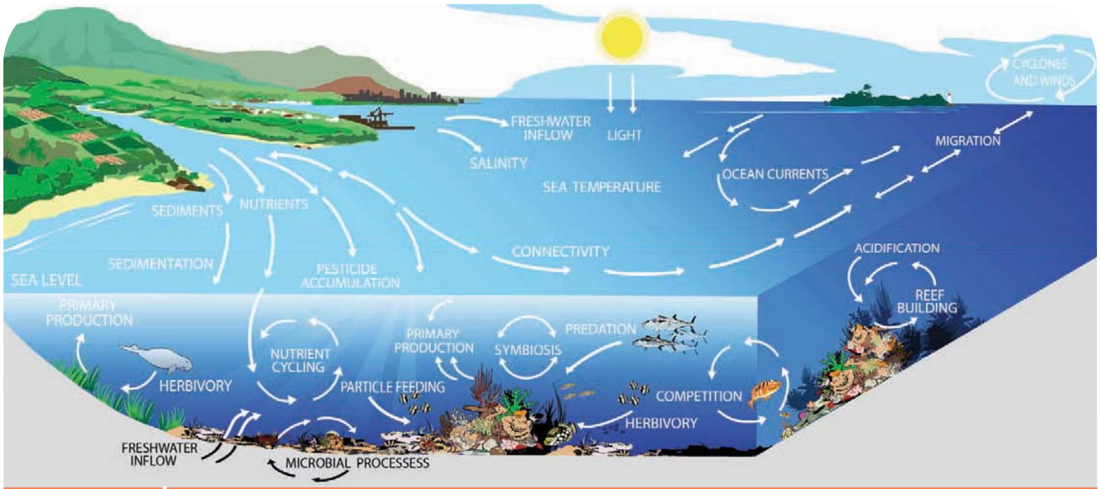


Figure 3.1 | **Major physical, chemical and ecological processes in the Great Barrier Reef**

Physical, chemical and ecological processes are all interconnected and the overall health of the ecosystem requires all to be in good condition.

Australia Current. The East Australia Current transports water from the Western Pacific Warm Pool, the Earth's greatest mobile body of heat, onto the Great Barrier Reef.

There are many currents, counter-currents and eddies on the continental shelf, both in response to the major offshore currents and driven by wind and tides. As these transport marine larvae, they are responsible for the relatively high level of biological similarity around the margins of the Coral Sea as well as a gradient of biodiversity southward down the Great Barrier Reef (Section 2.1). For example, nutrient-rich tidal jets are responsible for the existence of the *Halimeda* banks in the northern part of the Great Barrier Reef (Section 2.2.3). Likewise, because they carry larvae of some species, the minor currents assist with genetic dispersal within and between reefs. The currents on the Great Barrier Reef also transport hatchling marine turtles from their nesting beaches to the wider South Pacific Ocean.

There is little information about whether ocean currents on the Great Barrier Reef are changing.

Ocean currents vary naturally and there is insufficient evidence to know if patterns are changing in the Great Barrier Reef.

3.2.2 Cyclones and wind

In the tropics, seasonal wind patterns generally shift from a predominance of southeasterlies to northeasterlies from winter to summer, respectively. Changes in wind direction and intensity can

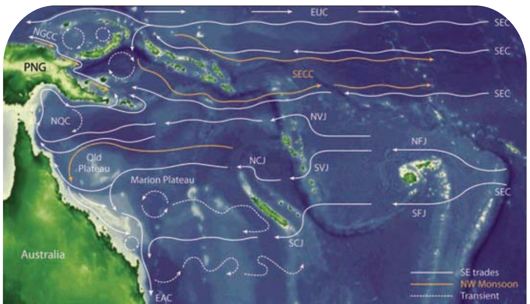


Figure 3.2 | **Surface ocean currents in the south west Pacific Ocean[1]**

SEC – Southern Equatorial Current, SECC - Southern Equatorial Counter Current, NQC – North Queensland Current, EAC – East Australia Current, NQCC - North Queensland Counter Current, NCJ – North New Caledonia Jet, NVJ – North Vanuatu Jet, SVJ – South Vanuatu Jet, NFJ – North Fiji Jet, SFJ – South Fiji Jet, EUC – Equatorial Undercurrent. PNG – Papua New Guinea.

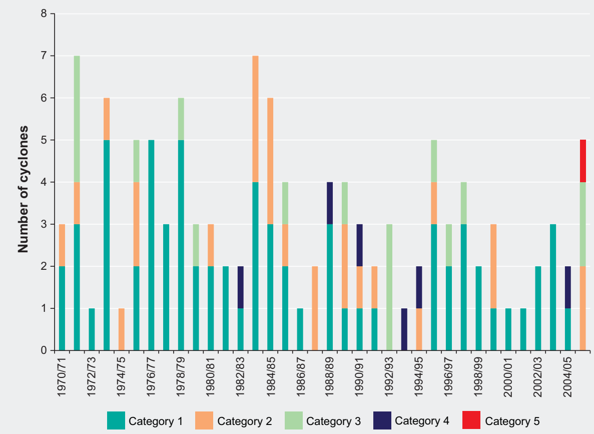


Figure 3.3 | **Number and severity of cyclones occurring within boundaries of the Great Barrier Reef, 1970 - 2006**

From the wet seasons of 1970/71 to 2005/06 there have been 116 cyclones occurring on the Great Barrier Reef, with only one category 5 cyclone (cyclone Larry) during that period. Since 2005/06 there have been another two category 5 cyclones in the Great Barrier Reef Region. (Data from the Bureau of Meteorology)

There is no evidence of more frequent cyclones but there is evidence of increased intensity.

dramatically change the shape of islands[2] and the coast and play a major role in determining ocean currents.

Cyclones regularly devastate coral and other communities at a local level. From the summer of 1970/71 to that of 2005/06, 116 cyclones occurred on the Great Barrier Reef (figure 3.3). There is potential for changes in cyclone activity associated with climate change (Section 5.2.1).

In 2009, cyclone Hamish, a category five cyclone, traversed the outer edge of much of the Great Barrier Reef. It had maximum wind gusts of up to 160km/h. The cyclone moved south along the Great Barrier Reef, from offshore Bowen through to the Swain Reefs, offshore Gladstone. The impacts are being investigated but preliminary evidence suggests the extent of damage is considerable (Section 2.2.2).

3.2.3 Freshwater inflow

Rivers draining into the Great Barrier Reef have periods of low or no flow lasting from months to years alternating with short periods of flood. Wet Tropics rivers (north from Ingham) have some flow most of the time and generally flood at least once per year. Dry Tropics rivers (south from Townsville) may have little or no flow much of the time and have significant floods once every two to three years (e.g. Burdekin River) or longer (e.g. Fitzroy River).[3]

Freshwater flows may be affected by changes in drainage patterns in the catchment.

The catchments in the Wet Tropics area contribute a large proportion of the freshwater flowing into the Great Barrier Reef, both in total freshwater flow (figure 3.4) and in relation to their catchment size (figure 3.5). From 2004 to 2007, the flow of freshwater into the Great Barrier Reef was significantly lower than the long-term average, principally because of drought throughout the catchment.

Patterns of freshwater flow onto the Great Barrier Reef have changed through river and land management practices (Section 5.4.1). Although knowledge is increasing, the full extent of how natural environmental flows have altered and any subsequent effects on the Great Barrier Reef remain unknown.

As well as freshwater reaching the Great Barrier Reef through creeks and rivers, it is also delivered via groundwater through depressions in the seabed known as 'wonky holes'[6] (figure 3.6).The seepage of freshwater through the seabed is important at a local level as groundwater may contain significantly

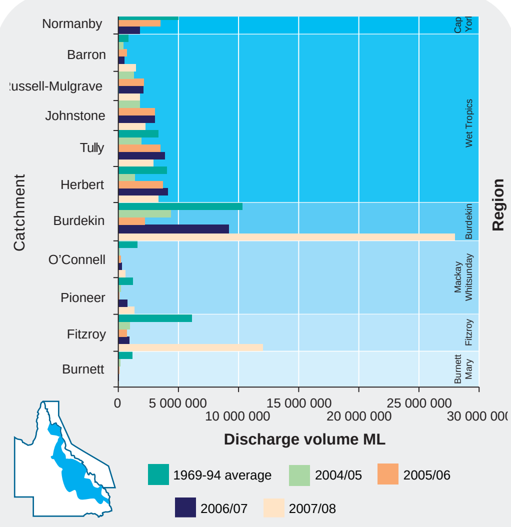


Figure 3.4 **Freshwater inflow to the Great Barrier Reef from major catchments, 2004-2008[4]**

Much of the freshwater entering the Great Barrier Reef comes from catchments in the Wet Tropics (Barron, Russell-Mulgrave, Johnstone, Tully, Herbert). Flows from the larger, drier catchments (such as the Burdekin and Fitzroy) are more variable. Drought conditions in much of the catchment have meant lower flows of freshwater into the Great Barrier Reef during 2004 to 2007 compared to the 1969-94 average.

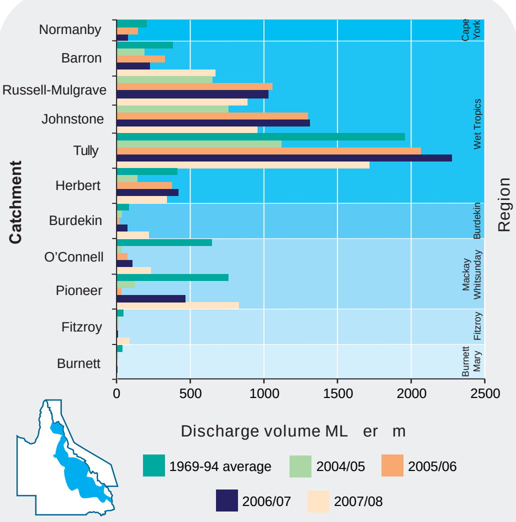


Figure 3.5 **Freshwater inflow to the Great Barrier Reef by area for major catchments, 2004-2008**

For each square kilometre in a catchment, the Wet Tropics (Barron, Russell-Mulgrave, Johnstone, Tully, Herbert) contribute larger volumes of freshwater to the Great Barrier Reef when compared to the larger, drier catchments (for example the Burdekin and Fitzroy). (Data on discharge from Queensland Department of Environment and Resource Management. Data on catchment size from Furnas, 2003.[5])

increased nutrient loads. An additional nutrient source in the groundwater comes from bird guano on coral cays.[7]

In 2008 and early 2009 there was major flooding and exceptionally high rainfall in the central and northern parts of the Great Barrier Reef catchment, causing a large influx of freshwater into the Great Barrier Reef. The consequences of this influx are being investigated.

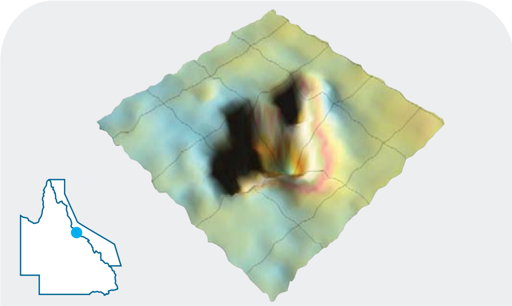


Figure 3.6 **Places where freshwater seeps through the seafloor[6]**

Freshwater enters the Great Barrier Reef through the seafloor in seabed depressions known as 'wonky holes'. This acoustic image is of a 'wonky hole' in Halifax Bay near Townsville at a depth of about 20m. Each grid square is 10x10m and the hole itself is about two metres deep.

3.2.4 Sedimentation

Exposure of the Great Barrier Reef to terrestrial sediments has increased, especially in inshore areas.

Inflow of sediments onto the Great Barrier Reef is a natural phenomenon which has been ongoing since modern sea level was reached 6000 years ago. However, over the past 150 years sediment inflow onto the Great Barrier Reef has increased four to five times[8], and five to 10 fold for some catchments[9] (see Section 5.4.1).

Flood plumes often extend as far as the inshore islands of the Great Barrier Reef and can even reach the outer reefs in extreme events.

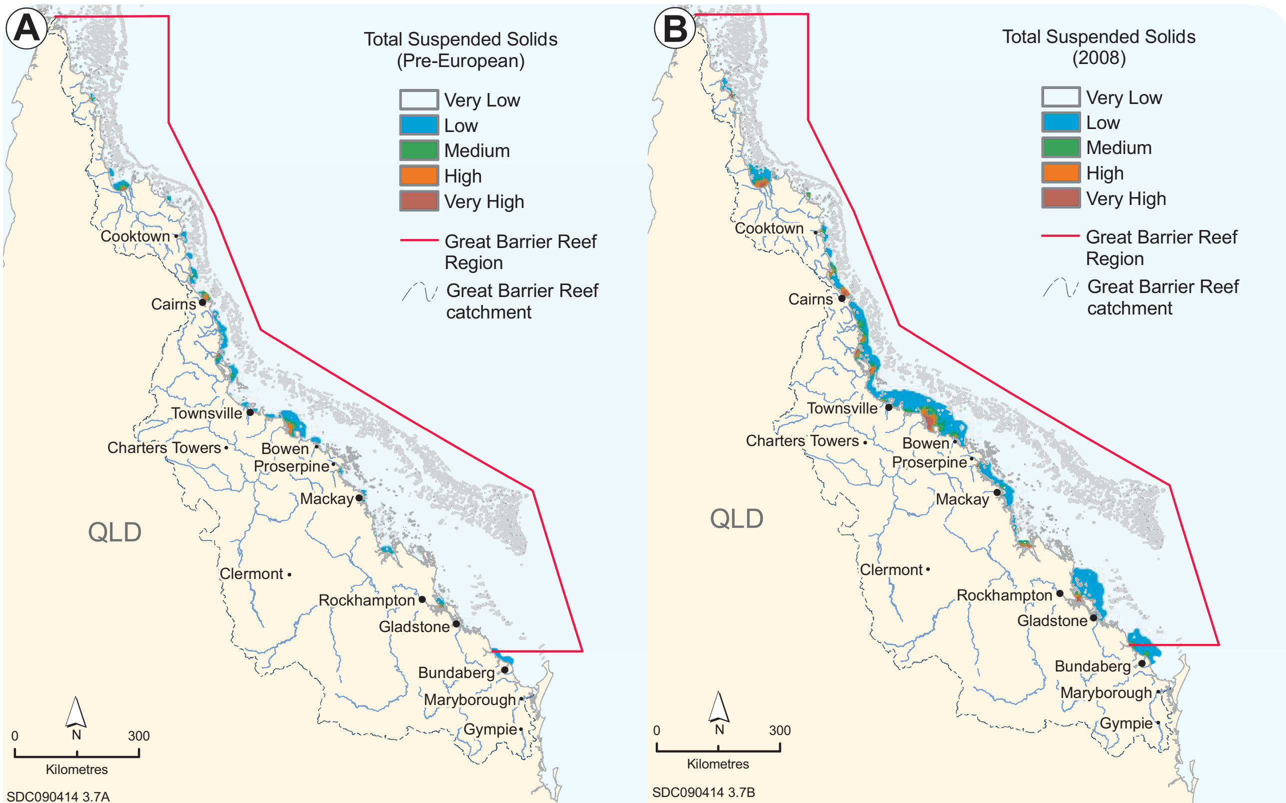


Figure 3.7 **Changes in exposure to sediments, Great Barrier Reef[8]**

Compared to likely conditions prior to European settlement, development in the catchment has meant that the area of the Great Barrier Reef exposed to sediments has increased markedly. This map shows results of a model of the exposure of the ecosystem to total suspended solids before European settlement (A) and in 2008 (B).

The coastal zone is clearly the part of the Great Barrier Reef most exposed to increased sedimentation, especially areas close to river mouths (figure 3.7). The area of the Great Barrier Reef affected by sedimentation is increasing substantially as a result of land management practices (Section 5.4.1), to the point where sediment is reaching mid-shelf reefs for the first time in their geological history (figure 3.7).

3.2.5 Sea level

Sea levels have risen in the Great Barrier Reef and are projected to rise further.

Records of variations in sea level for Townsville, in the central Great Barrier Reef, since 1959 (figure 3.8) show an average increase of 1.2mm per year. The rate of increase may be accelerating with records of sea level at Cape Ferguson near Townsville showing an average increase of 2.9mm every year between 1991 and 2006.[10] By the standards of past geological history of the Great Barrier Reef, this current sea level change is miniscule. However, it is believed that sea level had been very constant for the past 6000 years, resulting in a well-defined depth profile across virtually all reefs. Most reefs will probably be able to accommodate a sea level rise of 3mm per year as the maximum rate of reef growth is about twice this.[11] However, as the rate of sea level rise increases (Section 5.2.1), the depths at which coral reefs are able to survive may change as well as the shape and existence of some cays and islands.

3.2.6 Sea temperature

Average water temperature across the Great Barrier Reef is increasing.

Temperature is a key environmental factor controlling the distribution and diversity of marine life. It is critical to reef building (Section 3.4.7) and controls the latitudinal limits of both corals and coral reef growth. When temperature limits are exceeded, physiological processes may break down. For coral reefs, the most critical mechanism affected is the symbiotic association between animals (such as corals and clams) and the algae which live within their tissues (see Section 5.2.1).

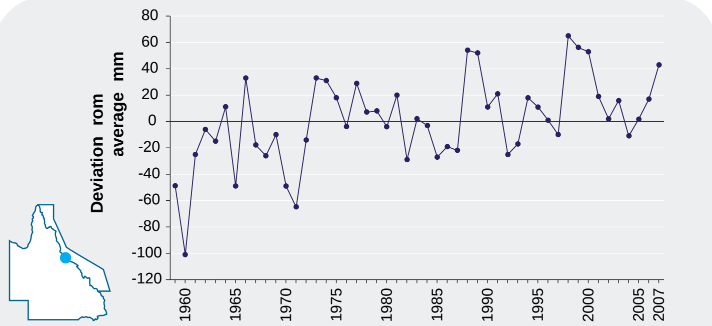


Figure 3.8 **Average sea level recorded for Townsville, Australia, 1959-2007**

From 1959 to 2007 sea level in Townsville, Australia, has varied 160mm around the average sea level. However, since the 1970s, the deviation from the average sea level has tended to be above the average. Between 1991 and 2006, the increase was an average of 2.9mm per year. (Data from the Permanent Service for Mean Sea Level[12])

When warmed water is pulsed onto the Great Barrier Reef, especially during El Niño years, it is further heated in the lagoon. This temperature stress, in combination with sunlight, causes mass bleaching in corals (see Section 5.2.1) and other reef organisms which have symbiotic algae in their tissues.

In addition, cold water bleaching has occurred in the southern part of the Great Barrier Reef (Heron Island, 1999).[13] As with warm water bleaching, the rate of change in water temperature was an important factor in the bleaching event.

The temperature gradient along the Great Barrier Reef has shifted markedly over the last century (figure 3.9). When averaged across the last 30 years, sea surface temperature in the Great Barrier Reef has increased by about 0.4°C, compared to records averaged across 30 years in the late 1800s.[10] The two warmest five-year average sea surface temperatures have been recorded in the last decade (figure 3.10). Analyses of coral cores in corals dating back to the mid seventeenth century suggest that current temperatures are warmer now than at any other time in that period. Gradual overall increases in sea temperatures are an effect of climate change (Section 5.2.1).

3.2.7 Light

Levels of light control the depth range of marine plants (e.g. seagrass meadows, algae) as well as all animals which have a symbiotic dependence on plants (e.g. corals). Light decreases in the water column according to the amount of sediment in the water[14] (Section 3.2.4). Thus, it becomes limiting at shallow depths in the coastal zone (where corals seldom grow deeper than five metres) compared to outer reefs and other habitats (where corals commonly occur at 80m).[15] Light, a key to the symbiotic relationship between corals and the algae in their tissues, is critical to coral reef building (Section 3.4.7) and for coralline algae which cement coral debris into limestone. It is also a major factor controlling the growth form of corals which, in turn, creates the physical

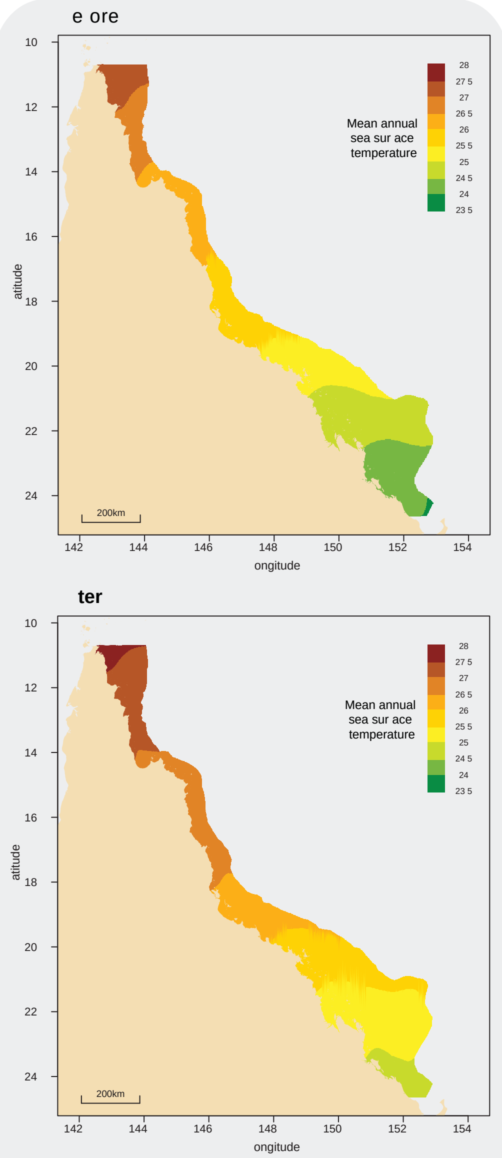


Figure 3.9 **Sea surface temperature in the Great Barrier Reef, before 1930 and after 1990**

The average temperature of the waters in the Great Barrier Reef is becoming warmer. (Images courtesy of the ATLAS)

characteristics of reef-slope habitats. Turbid areas can support high coral, macroalgae, fish and octocoral diversity. However, studies indicate that the loss of light from increases in sedimentation is affecting inshore areas.[14]

3.3 Current state and trends of chemical processes

The components of chemical processes on the Great Barrier Reef include nutrient cycling, pesticide accumulation, ocean acidity and ocean salinity.

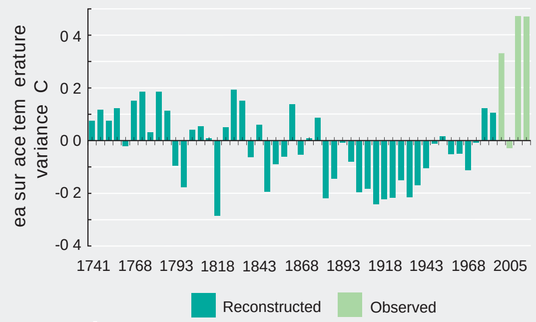


Figure 3.10 **Reconstructed and observed changes in five-year average sea surface temperature in the Great Barrier Reef, 1741-2005[10]**

Reconstructed (1741 to 1985) and observed (1985 to 2005) five-year average sea surface temperature differences from the long-term average for the Great Barrier Reef. The three hottest five-year averages have all been in the last 20 years.

3.3.1 Nutrient cycling

Nutrients have a critical role in maintaining biodiversity, yet most nutrient concentrations (e.g. nitrogen, phosphorus) in the open ocean are very low. Open oceans are effectively nutrient deserts. Nitrates, in particular, severely limit productivity. Open ocean coral reefs accommodate nutrient deficiency by having a high level of nutrient recycling within individual ecosystems. Reefs near land masses are less dependent on this process as additional nutrients are derived from terrestrial sources.

Within the Great Barrier Reef, both normal and above normal nutrient levels are closely associated with terrestrial runoff[16] (Section 5.4.1). Recent monitoring is developing an increasingly detailed understanding of the changing exposure to nitrogen and phosphorus in the Great Barrier Reef ecosystem.[17] Trends in five parameters (total dissolved nitrogen, total dissolved phosphorus, particulate nitrogen, particulate phosphorus, suspended solids) showed generally decreasing patterns since the early 2000s. Longer term trends back to the 1990s are still under analysis.[17] Notwithstanding these recent trends, dissolved inorganic nitrogen and phosphorous continue to enter the Great Barrier Reef at greatly enhanced levels, two to five times for nitrogen (figure 3.11) and four to 10 times for phosphorus relative to pre-European settlement.[18]

Unless concentrations are lethally high, nutrients have little direct adverse effect on individual coral reef species, however nutrients have enormous impacts on the ecosystem. For example, nutrients may encourage planktonic algal blooms which, if

Exposure to nutrients has increased for much of the Great Barrier Reef especially in inshore areas.

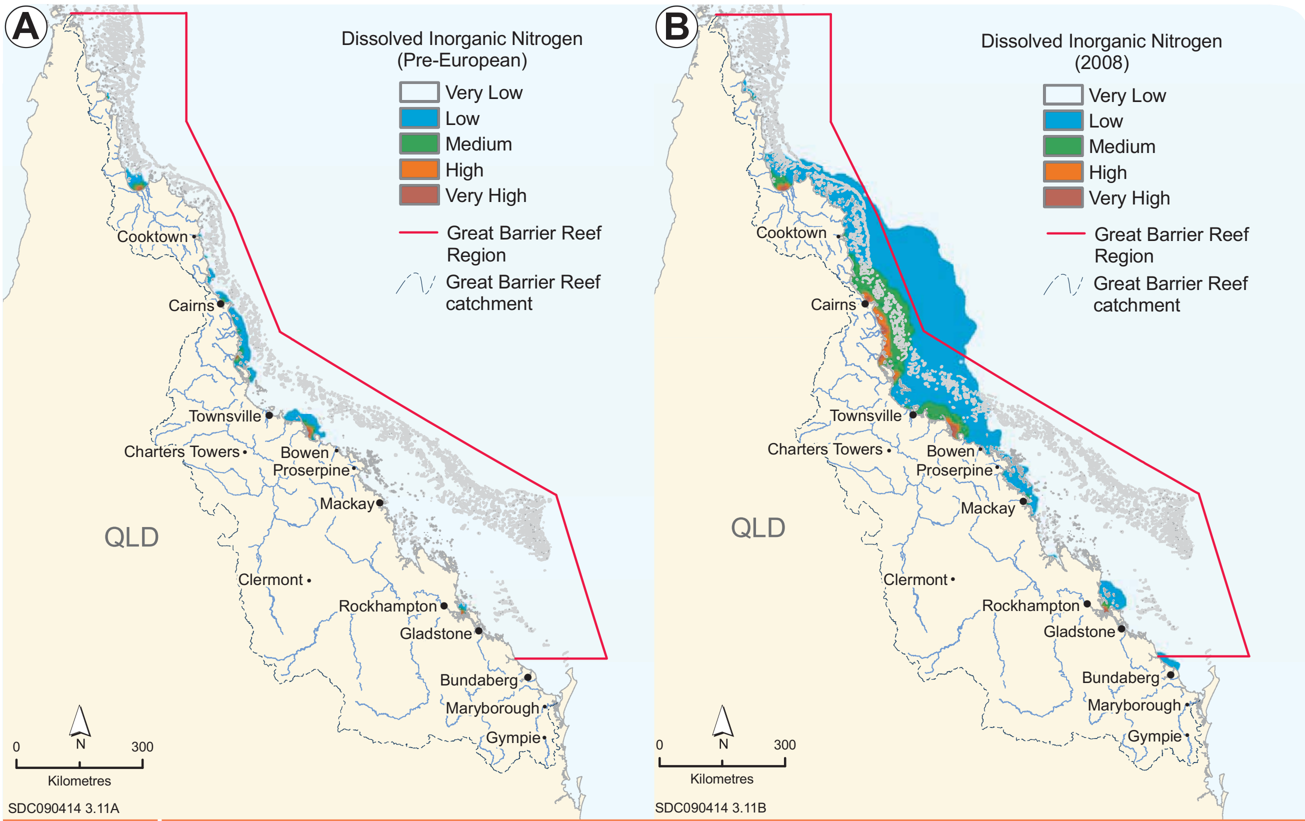


Figure 3.11 | **Changes in exposure to dissolved inorganic nitrogen, Great Barrier Reef**[8]

The effects of increased concentrations of nutrients such as dissolved inorganic nitrogen are likely to be felt far from shore, especially adjacent to the Wet Tropics. This map shows the modelled exposure of the ecosystem to dissolved inorganic nitrogen before European settlement (A) and in 2008 (B).

The world's oceans are becoming more acidic, affecting the growth of corals.

There are traces of pesticides in the Great Barrier Reef environment, the impacts of which are largely unknown.

coinciding with the spawning of crown-of-thorns starfish larvae, greatly increase the latter's chances of survival. Particulate nutrients are a direct food source for crown-of-thorns starfish larvae.[19] Increased nutrients may also result in algae out-competing coral. This imbalance is in large part held in check by herbivores (usually fish) (Section 3.4.4).

In addition, more nutrients are thought to be entering the Great Barrier Reef ecosystem through seepage of groundwater through the seafloor (Section 3.2.3). The discharge of sewage from vessels operating in the Region contributes a very small load of additional nutrients.[20]

3.3.2 Pesticide accumulation

Pesticides, including herbicides, insecticides and fungicides, are of concern because, by their very nature, they are poisonous and there is no natural background exposure to them. Nearly one-third of the Great Barrier Reef, especially inshore, is now exposed to herbicides (figure 3.12).

Pesticides used in the Great Barrier Reef catchment (Section 5.4.1) such as DDT (which was totally banned in 1987) and dieldrin have been detected in crabs at a number of river mouths along the Great Barrier Reef[21] and in marine mammal tissue.[22] Contemporary pesticides (such as diuron, atrazine and tebuthiuron) are now being detected and measured in inshore waters along the coast (figure 3.13) through regular monitoring which has only recently commenced.

3.3.3 Ocean acidity

The acidity of the ocean is measured by its pH, a measure of hydrogen-ion concentration. It is estimated that, globally, an increase in the amount of carbon dioxide absorbed by the ocean has already caused a decrease in oceanic pH of 0.1 units compared to the long-term average (Section 5.2.1); however there is no information about local and regional variability on the Great Barrier Reef. Unprecedented declines in calcification of 14.2 per cent in at least one coral species (*Porites* spp.) since 1900 has already been observed in the Great

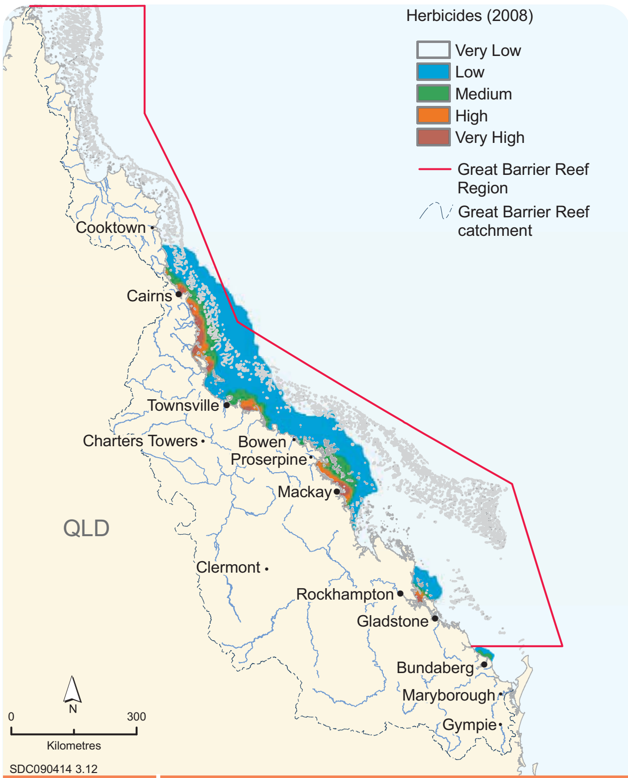


Figure 3.12 **Exposure to herbicides, Great Barrier Reef[8]**

This map shows the results of a model of the current exposure of the Great Barrier Reef ecosystem to herbicides. Inshore areas next to developed coastlines are more exposed to herbicides. There would have been no such exposure before European settlement.

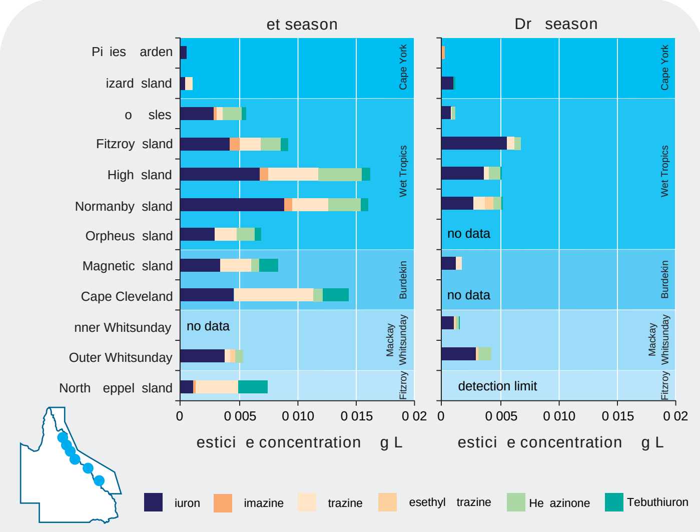


Figure 3.13 **Pesticides in Great Barrier Reef waters, 2007/08[23]**

Pesticides have been detected at all inshore monitoring sites on the Great Barrier Reef. Concentrations are higher in the wet season when river flows are greater and pesticides are generally applied in agricultural areas. The highest concentrations were detected in the Wet Tropics (Fitzroy, High, Normanby and Orpheus Islands) and the Burdekin area (Magnetic Island and Cape Cleveland).

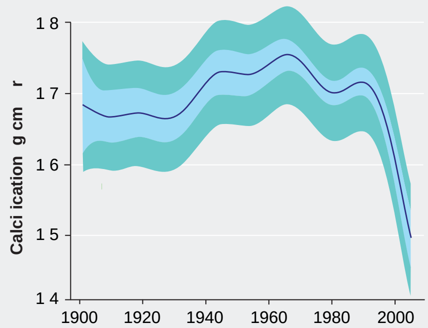


Figure 3.14 **Changes in calcification in *Porites* spp., Great Barrier Reef, 1900-2005[24]**

This graph shows an overall decrease in the rate of calcification in *Porites* corals on the Great Barrier Reef since 1900. Since 1980, there has been a dramatic decrease in the calcification rate, which has been attributed to increasing acidification and increasing sea temperature stress. The light blue bands indicate 95 per cent confidence intervals for comparison between years, and the green bands indicate 95 per cent confidence intervals for the predicted value for any given year. Three hundred and twenty-eight colonies from 69 reefs were sampled throughout the Great Barrier Reef. (g/cm²/yr =grams per square centimetre per year)

Barrier Reef (figure 3.14) with both increasing temperature stress and increasing acidification suggested as the causes.[24]

3.3.4 Ocean salinity

Flood plumes from the creeks and rivers in the Great Barrier Reef catchment naturally form a thin layer of freshwater on the surface of the heavier seawater, and may extend across the continental shelf to the mid-shelf and outer reef. This can result in extensive fluctuations in ocean salinity, especially in intertidal and shallow habitats. Flood plumes from the Dry Tropics catchments are larger and longer lasting than from the more frequent floods from the Wet Tropics.[25] If the severity of storms increases as a result of climate change (Section 5.2.1), then there could be an increase in the amount of freshwater entering the Great Barrier Reef. Even very heavy rainfall directly on the ocean can lower the salinity at the surface and this has resulted in localised impacts especially when the tides are low.

The salinity of Great Barrier Reef waters is generally stable, with local short-term fluctuations after flood events, mostly close to the coast.

Many marine plants and animals are highly susceptible to low salt levels. Coral larvae are readily killed by low salinity associated with floods.

However, mass spawning, typically occurring around October and November on the Great Barrier Reef, is unlikely to coincide with very heavy monsoonal rainfall which occurs during the summer wet season of December to March.

3.4 Current state and trends of ecological processes

Changes in the physical and chemical environment are likely to be causing changes in microbial processes, but there is little information available.

The plants and animals of the Great Barrier Reef ecosystem can be broadly divided into six ecological groups: top predators (such as sharks and seabirds), predators (such as coral trout), herbivores (such as parrotfish and dugongs), particle feeders (such as sea cucumbers and crabs), microbes (such as bacteria) and primary producers (such as macroalgae, seagrass and the symbiotic algae in corals).

Most populations of particle feeders are healthy although sea cucumbers are at risk of local depletion.

These ecological groups are connected through a robust and complex food web (figure 3.15) which is a foundation of the ecosystem. At the same time, there are other ecological processes, symbiosis, reef building, competition and connectivity which operate across all levels of the food web.

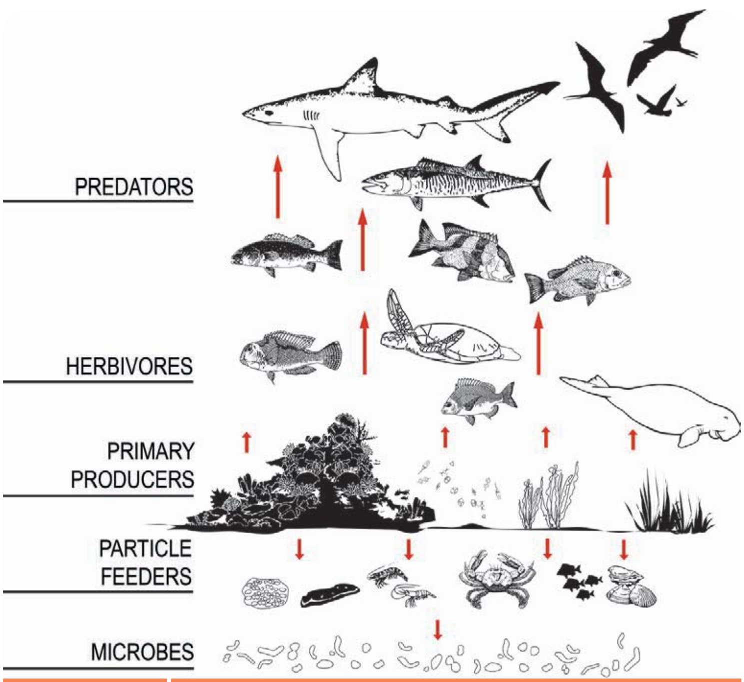


Figure 3.15 A simple food web of the Great Barrier Reef

Each major ecological group plays a role in the food web of the Great Barrier Reef ecosystem. Some species perform more than one role, for example corals are principally primary producers because of their close partnership with single-celled algae, but they are also particle feeders.

3.4.1 Microbial processes

The role of microbes in trophic interactions is not known in detail, having received only very limited scientific study. Marine snow, a continuous shower of mostly organic detritus falling from the upper layers of the water column, and the increasing frequency of diseases (Section 3.5.1) are visible outcomes of changes in bacterial levels in the water column and in benthic organisms. However, most microbial processes remain invisible. Some, like anoxic events (when the water become completely depleted of oxygen below the surface levels), have destructive outcomes. Others, including the processing of detritus and the maintenance of biologically active substrates, are fundamental to the functioning of benthic ecosystems. Microbial processes are very responsive to ambient organic and inorganic nutrient levels. There is limited information on trends of microbes (and hence the roles they perform) on the Great Barrier Reef.

3.4.2 Particle feeding

Particle feeders comprise a large sector of seabed organisms, recycling nutrients from dead plants and animals. Particle feeders include a large proportion of small fish as well as most marine invertebrates (e.g. sea cucumbers, scallops, sponges, corals and many crustaceans, such as prawns, crabs and lobsters). All ingest detritus, bacteria, plankton and other particulate nutrients on the seafloor and from the water column. They do this through a wide range of mechanisms including filter and ciliary feeding (in sessile animals such as corals) and scavenging (in most mobile animals).

The clay fraction of sediments, which has little nutrient value, is very detrimental to particle feeders as their feeding mechanisms are readily choked or are kept clean at a high metabolic cost. The primary impact of increases in sedimentation is, therefore, on this trophic group.

Ecosystems that have become very degraded through extreme nutrient levels, anoxia or acidification are almost entirely populated with benthic particle feeders.

Of those species for which information is available, most populations of particle feeders in the Great Barrier Reef are in good condition, including most that are fished or harvested. However, some sea cucumber species have been extensively harvested

(Section 2.3.3) and some populations do not appear to have recovered (Section 7.2.4).

3.4.3 Primary production

Most food webs are ultimately based on primary production: the production of food by photosynthesis using energy from the sun. In tropical marine ecosystems, contributions to primary production come not only from plants such as macroalgae, turf algae, seagrasses and mangroves, but also, in large part, from microscopic free floating algae (phytoplankton), and from corals, which have microscopic algae (zooxanthellae) within their tissues.

All primary production is closely linked to levels of inorganic nutrients in all oceans.[26] Primary production by phytoplankton in the water column is highest in inshore areas in the central and northern Great Barrier Reef, up to twice as much as that recorded in the far northern Great Barrier Reef.[26] This elevated primary production is most likely related to elevated nutrient concentrations resulting from agricultural development in adjacent catchments.[26] It is simply not known if patterns of primary production are changing in other habitats.

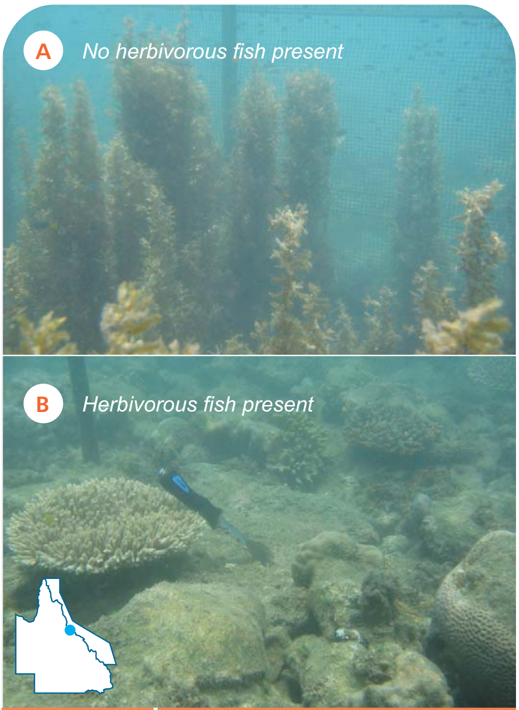


Figure 3.16 **The importance of herbivorous fish**

Herbivorous fish play a major role in the balance between coral and algae. In this experiment a cage excluded herbivorous fish from part of a coral reef (A) which became overgrown with macroalgae. When the cage was removed, the algae was rapidly consumed (B). (Photos courtesy of L. McCook)

There is insufficient evidence to know if overall patterns of primary production are changing.

3.4.4 Herbivory

Consuming plants for food (herbivory) is a critical process for the health of coral reefs. By feeding on the algae of a reef, herbivores (such as some fish and green turtles) reduce the amount of algae, generally making space for corals to regrow and increase in numbers after disturbances.

Herbivores have a particularly important role in maintaining reef ecosystems because, without their constant presence, all reefs would be rapidly overtaken by algae.[27 28] Fish are the main herbivores on the coral reefs of the Great Barrier Reef, elsewhere sea urchins such as *Diadema* are important in some coral reef ecosystems.[29]

Studies on the Great Barrier Reef suggest that current populations and diversity of herbivorous fish are sufficient to control algal growth on most offshore reefs[30 31] (figure 3.16), in part because there is minimal direct pressure on their populations. They are not targeted for commercial or recreational fisheries. This is in contrast to coral reefs in much of the Caribbean[29] and South-East Asia[32], where herbivores have been increasingly overfished, causing algal overgrowth and poorer reef quality.

Seagrass and macroalgae are the main benthic plant groups on the Great Barrier Reef, the former being the food source of dugongs and both being a food source for green turtles. The substantial decrease in the number of large herbivores on the Great Barrier Reef (dugongs and green turtles) is thought to have significantly affected the process of herbivory in the ecosystem.

Populations of herbivorous fish are healthy and generally not under pressure; however larger herbivores, like dugongs, have declined along the urban coast.

3.4.5 Predation

Predators and top predators in coral reef ecosystems include most big bony fish and sharks, as well as a wide array of smaller finfish and invertebrates, seabirds, marine turtles and marine mammals. Predation (animals consuming other animals) has a fundamental influence on marine ecosystems by controlling the abundance of many prey animals and causing a range of cascading effects through the food web.

Most predator populations are relatively healthy but a few species are under serious pressure, with potential flow-on impacts.

At some locations on the Great Barrier Reef there has been a marked decrease in populations of coral trout and some reef shark species[33 34] (Section 2.3.5) both of which are targeted by fishing activities. Sharks are also incidentally caught when other species are being targeted. This decline in predator abundance has resulted in an increase in their prey species in some places (figure 3.17). There are few other similar studies for the Great Barrier Reef.

The significance of predation to the Great Barrier Reef ecosystem is demonstrated by recent results showing that outbreaks of crown-of-thorns starfish are significantly reduced on reefs protected from fishing (figure 3.18). Fewer outbreaks of crown-of-thorns starfish mean more, intact coral reef habitats, in turn affecting the entire coral reef system.

Recent evidence from remote Pacific Ocean coral reefs suggests that, on intact coral reef ecosystems, top predators such as very large predatory fish and sharks, are much more abundant than previously realised (figure 3.19). The role of predation on coral reef habitats is still not fully known but clearly there are links between predators and prey with flow on effects on habitats (e.g. coral reefs and algae).

Declines in some Great Barrier Reef predatory species, such as some sharks and coral trout[33 34] (Section 2.3.5), most marine turtles (Section 2.3.6), seabirds (Section 2.3.7) and marine mammals (Section 2.3.8) suggests that predation in Great Barrier Reef food webs may have been altered significantly.

3.4.6. Symbiosis

Symbiosis, the interdependence of different organisms for the benefit of one or both participants, is much more prevalent in the oceans than on land. Examples include the association between giant anemones and anemone fish or the *Chelonibia* barnacle found on marine turtles.[38]

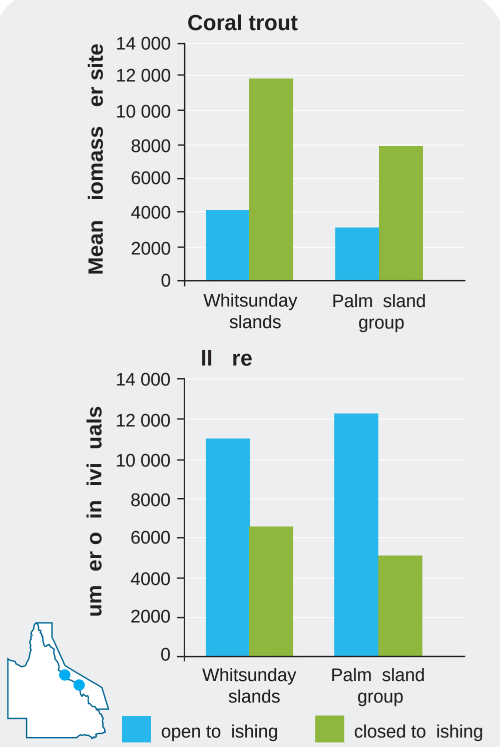


Figure 3.17 | Effects of predation on prey species, Great Barrier Reef[35]

A study in the Whitsunday Islands and the Palm Island group demonstrates that fewer predators on coral reefs can result in an increase in prey species. The biomass of coral trout is measured in grams per 1500m² and the density of prey species is the number of individuals in a 1500m² area. The areas open to fishing included both the Habitat Protection Zone and the Conservation Park Zone.

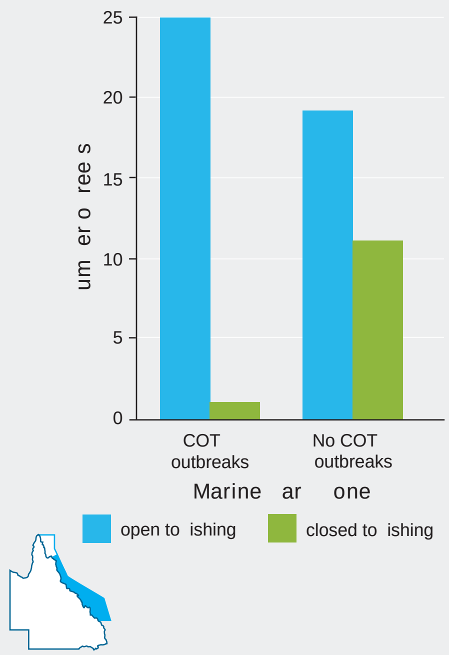


Figure 3.18 | Crown-of-thorns starfish (COTS) outbreaks across zones, Great Barrier Reef, 1994-2004[36]

There are significantly fewer crown-of-thorns starfish outbreaks in zones closed to fishing (green bars) in the Great Barrier Reef. For both zones open to fishing (blue bars) and zones closed to fishing, the graph shows the number of surveyed mid-shelf reefs for which an outbreak was recorded at some time between 1994 and 2004 and those where no outbreak was recorded.

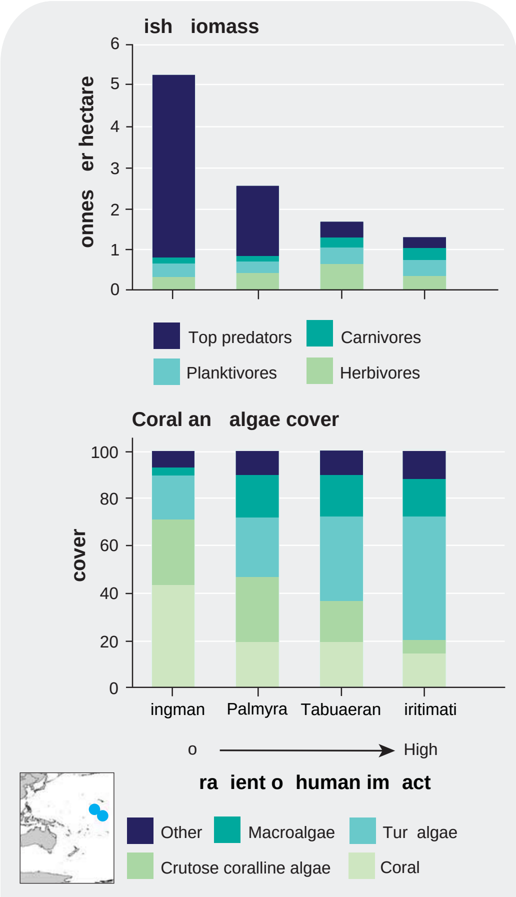


Figure 3.19 Changes in the ecological structure of coral reefs with increasing disturbance[37]

As more impacts are felt on the reef ecosystem, ecological structure changes, as seen on these remote Pacific atolls.

One of the most significant symbioses is that between hard corals and zooxanthellae (*Symbiodinium* - a genus of dinoflagellates, simple, single-celled plants), since it is fundamental to the growth of corals, and hence the key to reef-building. Zooxanthellae symbiosis is not just found in hard corals; it also occurs in other cnidarians (for example, soft corals, anemones) as well as in an assortment of other animals encompassing sponges, flatworms and molluscs (including giant clams).

Zooxanthellae photosynthesise like other green plants, however up to 95 per cent of the nutrients produced are used by the host organism.[39] This is the food source of reef-building corals: reef building is literally powered by the sun via the photosynthesis of algae. Coral bleaching is a breakdown of this symbiotic relationship with the stress to the corals causing them to expel their zooxanthellae, thereby turning white. As the incidence of coral bleaching increases in the future (see Section 5.2.1), at least one symbiotic relationship will be affected. Importantly *Symbiodinium* exists as a number of strains with different tolerances for temperature which may have implications for coral reefs in the face of climate change[40]; it is likely that the relative prevalence of these strains will change in response to climate change.[41]

Little is known about most symbiotic relationships, although it is likely that the symbiosis that powers coral growth is changing in response to increasing sea temperatures.

3.4.7. Reef building

Reefs are a unique phenomenon of nature where whole ecosystems, acting in unison, effectively create their own habitats. This can only happen if algal photosynthesis powers the process, calcium carbonate is an unlimited resource and reef growth outstrips reef erosion. Reef building is therefore dependent on light to power algal symbiosis (Section 3.2.7), temperature to lift the rate of reef growth over that of erosion (Section 3.2.6) and the availability of carbonate ions to allow deposition of calcium carbonate (limestone) by corals, calcifying algae and other organisms (Section 3.3.3).

Rates of reef growth (accretion) can be measured directly from cores taken from reefs or by a wide range of indirect measures of carbonate production.[42] Normally, the maximum rate of reef growth is about 0.6m per century[11] although rates in optimal conditions may reach three times this.[43] These optimal conditions only occur where the water is shallow and clear, the currents are strong and the ocean pH is alkaline. These environments provide high light levels combined with continuous flushing and nutrient transport.

The rate of reef building may be beginning to slow.

At the same time that reefs are growing, they are also being eroded. Except when reefs are exposed to rainwater during intervals of low sea level, coral reef erosion currently occurs through physical abrasion (such as waves) and bioerosion (caused by molluscs, marine worms, sponges, crustaceans, echinoderms and fish).

Bioerosion is a greatly under-recognised process. A variety of organisms such as polychaetes, molluscs, sponges and barnacles bore into coral reefs and others, such as some fish and sea urchins, graze the surface of corals (to consume the algae living on and in the reef substratum) by biting and scraping. This biological activity results in the breakdown of the reef substratum.[44]

Information on calcification in long-lived massive corals from the inshore Great Barrier Reef indicates a decrease over the last two decades[24] (see figure 3.14). Qualitative information indicates that rates of bioerosion may be increasing on the Great Barrier Reef[44] because of the loss of hard coral cover (Section 2.2.2) and increasing nutrients (Section 3.3.1), sediments (Section 3.2.4) and ocean acidity (Section 3.3.3).

Coral recruitment plays an important role in the replenishment and structure of coral populations, and hence in reef building. This is especially important after disturbance events such as mass bleaching, since corals are major contributors to the physical structure of reefs, which is in turn important to many species. There is only limited monitoring of coral recruitment on the Great Barrier Reef, but available evidence does not indicate widespread declines.[17] Studies of variation in recruitment patterns of *Acropora* corals on the Great Barrier Reef found that reproductive capacity had more effect than adult abundance or geography.[45] The intensity and timing of spawning had a crucial impact on large scale patterns of recruitment.[46]

3.4.8 Competition

Competition for all resources, including space, nutrients and food is always intense in tropical marine ecosystems. This is partly because they are biodiverse, so that individual species have others to compete with and also because of the three-dimensional nature of habitats. Water, far more than air, is a medium that allows for high levels of biological interaction, nutrient transfer and therefore competition.

Competition between corals and algae appears normal except for some inshore areas, but there is little information about other types of competition.

Competition between corals and algae for space is a fundamental process on coral reefs.[47] For coral reefs to be maintained in the ecosystem there must be continual settlement and growth of new juvenile corals. This coral recruitment may be hampered if a reef becomes overgrown by algae, if water quality is seriously degraded, or if the supply of coral larvae is reduced.[48]

Changes in nutrient supply or in the consumption of algae (herbivory) are often the causes of changes in the balance between coral and algae (figure 3.20). In coral reefs that are under pressure there tends to be an increase in algae and a decrease in coral (figure 3.19, and figures 7.3 and 7.4).[49]

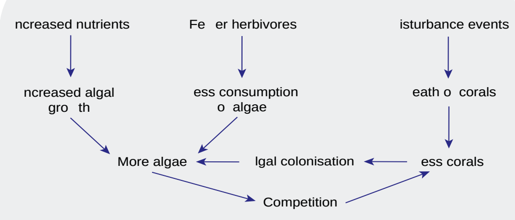


Figure 3.20 **The balance between coral and algae**

Competition between coral and algae is important to coral reefs and can be affected by increased nutrients, decreased herbivory and increased disturbances.[50 51] There are also various feedback connections, such as increased algae suppressing herbivore recruitment and fewer corals resulting in reduced coral replenishment. (Adapted from McCook, 1999[27])

There is little information about other types of competition in the Great Barrier Reef ecosystem, such as between hard corals and soft corals, or about changes in competition within habitats other than coral reefs. However, it can be assumed that reductions in the populations of species such as dugongs, marine turtles, predatory fish and sea cucumbers have affected natural competitive processes.

3.4.9 Connectivity

The subject of connectivity permeates every aspect of the Great Barrier Reef, including topics as divergent as nutrient flows, biogeographic patterns, migration paths, larval dispersal[52], biodiversity and genetics. Fundamental, as far as the Great Barrier Reef is concerned, is that every part of the ecosystem is connected in many ways to other parts and these connections may operate in short intervals of time, perhaps single generations or seasons.[53] It follows that any form of degradation in one area may ultimately affect many others.

There are many components to connectivity, including connections between estuarine and inshore habitats and those further offshore, north-south connections between habitats, connections between open water and seabed habitats and larger scale connections to environments well outside the Great Barrier Reef[53] like the Torres Strait, Coral Sea and the Coral Triangle to the north of Australia. Recent research on larval dispersal of corals and fishes between coral reefs on the Great Barrier Reef shows intact connectivity.[54 55]

Connectivity between marine environments and adjacent freshwater systems has been reduced through the loss of coastal wetlands (Section 5.3.1) and by modifications to the waterway flows through the construction of dams and weirs (see Section 5.4.1).

On a larger scale, migration is part of the process of connectivity. It is important for a number of species of conservation concern that live in the Great Barrier Reef for only part of the year, such as the humpback whale[56], green, loggerhead and hawksbill turtles[57] and some seabirds.[58] Some Great Barrier Reef fish species, like marlin, are also highly mobile and travel well beyond the Great Barrier Reef for parts of their lifecycle.[59] Conservation threats to these mobile species are often well beyond the Great Barrier Reef. For example, some marine turtles that nest or forage in areas hundreds, and even thousands, of kilometres away are injured or killed in these areas.

3.5. Current state and trends of outbreaks of disease, introduced species and pest species

A gauge of how well an ecosystem is functioning is the frequency and severity of outbreaks of diseases, introduced species and pests. Pests are defined as endemic species which have rapid population increases.

3.5.1. Outbreaks of disease

Disease, whether natural or otherwise, is a clear indicator of stress. Thus, coral reef ecosystems that have become much degraded in other countries are characterised by high incidence of diseases. For example, mass bleaching of the corals of Florida and the Caribbean are usually accompanied by disease outbreaks probably resulting from low energy reserves in surviving corals.[60] This phenomenon is being increasingly observed on the Great Barrier Reef and is likely to cause major impacts in the future.[61]

For the naturally occurring white syndrome disease, major incidents have been recorded after especially warm years and on reefs with high coral cover (figure 3.21), indicating a potential link between coral disease and increasing sea temperatures as a result of climate change (Section 5.2.1).

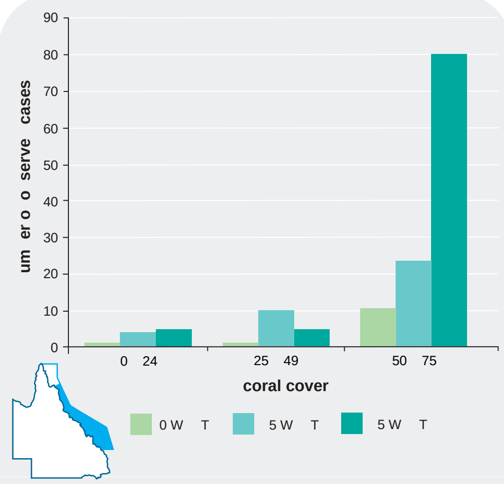


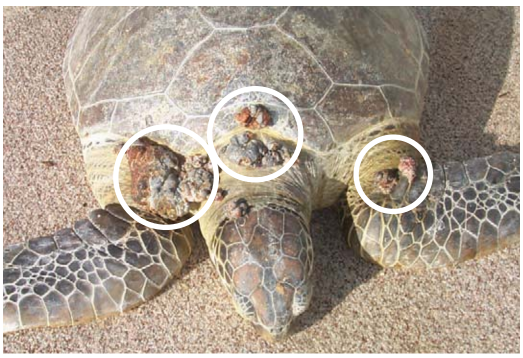
Figure 3.21 White syndrome coral disease on the Great Barrier Reef, 1998-2004[62]

White syndrome disease is more prevalent following extended periods of warmer sea temperatures and in areas of high coral cover. The graph displays the average number of observed cases of white syndrome disease in a $1500 m^2$ area for 48 sites across the Great Barrier Reef. The most observed cases were when coral cover was between 50 and 75 per cent and when there had been more than five continuous weeks during which the sea surface temperature was at least 1°C higher than normal (dark green bars) at those sites. WSSTA=the number of continuous weeks during which the sea surface temperature is at least 1°C higher than normal.

Most species and habitats remain adequately connected; connectivity between marine habitats and adjacent freshwater habitats has been reduced.

A few instances of fish disease have been reported from the Great Barrier Reef[63 64] and a small number of stranded marine mammals and turtles show signs of disease (*Cryptosporidium, Toxoplasmosis*) linked to human activities.[65 66] The very limited nature of these findings makes it difficult to interpret their significance.

The incidence of coral disease may be increasing in some areas.



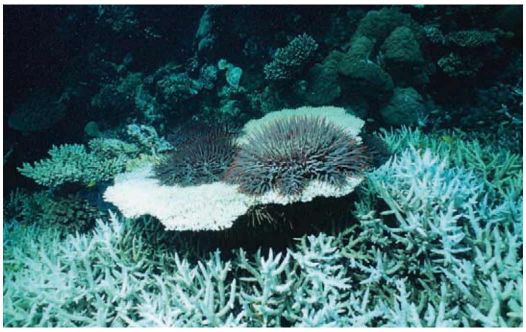
Fibropapillomatosis, believed to be caused by a virus, is most commonly found on green turtles. Higher incidence of the disease is noted in areas adjacent to large human populations and areas with low water turnover. (Photo courtesy of Col Limpus, Department of Environment and Resource Management).

3.5.2 Outbreaks of crown-of-thorns starfish

Outbreaks of crown-of-thorns starfish have been one of the major causes of coral death and reef damage on the Great Barrier Reef since surveys began in the 1960s. An outbreak of crown-of-thorns starfish is considered to be occurring when they are at densities greater than about 30 starfish per hectare.[67 68]

It appears that human impacts have increased the frequency and severity of crown-of-thorns starfish outbreaks.

The general scientific view is that occasional outbreaks are to some extent natural, but that human impacts have increased their frequency and severity. Suggested impacts include improved survival of larvae due to increased nutrients and phytoplankton[69] and reductions in predator populations.[70 71] Recent research has found that the number of reefs where outbreaks occur is markedly lower in zones closed to fishing (figure 3.18).



Crown-of-thorns starfish eating coral

The occurrence of introduced marine species adjacent to the Great Barrier Reef Region is increasing.

Outbreaks appear to arise on northern reefs, and gradually progress south over several years[72], although independent outbreaks have been observed in the Swains Reefs in the south (figure 3.22). It is believed larvae are carried south by ocean currents. Monitoring shows that the most recent wave of outbreaks, the third recorded, is declining.

Repeated damage from the crown-of-thorns starfish continues. The current management regime aims to address the potential human contributions to outbreaks by reducing runoff, managing fishing, and to control outbreaks at specific locations that are important for site-dedicated tourism operators.

Outbreaks of other species, such as algal blooms, may indicate the ecosystem is under increasing pressure.

3.5.3 Introduced species

Approximately 250 introduced marine species have been reported around Australia, some of which have had major ecological impacts.[73] Marine species normally arrive attached to the hulls of ships, in ballast water or occasionally through aquaculture operations. For the most part, tropical marine environments seem less susceptible to invasion than temperate ones.

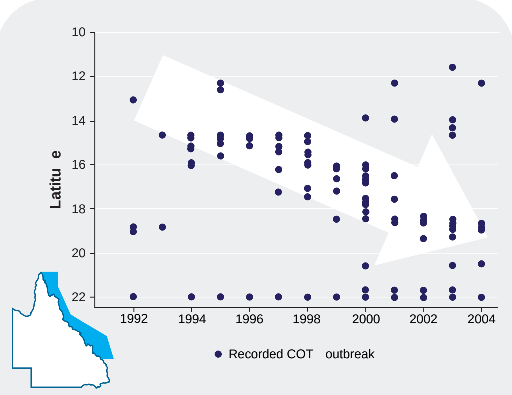


Figure 3.22 **The progression of a crown-of-thorns starfish outbreak along the Great Barrier Reef[36]**

Like the two previous outbreaks since the 1960s, the most recent outbreak of crown-of-thorns starfish progressed as a wave from north to south, taking about 10 years.

Introduced marine species (Asian green mussel, Asian bag mussel) have been found in ports (Section 4.5.3) along the Great Barrier Reef coastline, although none have been recorded beyond these ports. Introduced island species are another matter as seabird and turtle nesting grounds are readily affected by introduced species such as rats and dogs. Insect invasions have caused serious declines in *Pisonia* forests which are major nesting sites for several seabird species.

3.5.4 Other outbreaks

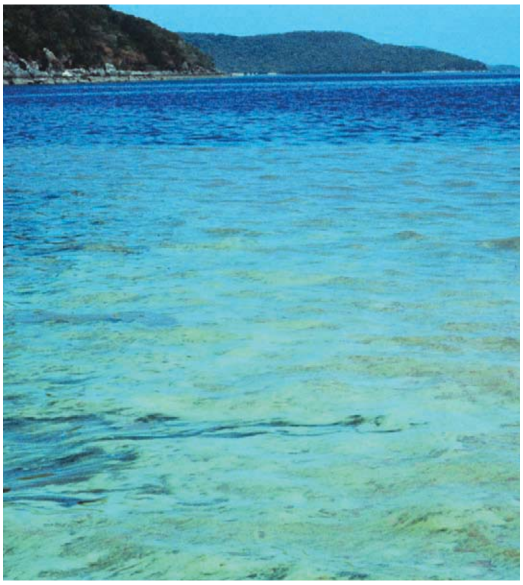
There have been periodic increases on the Great Barrier Reef in some naturally occurring species. For example, blooms of the cyanobacterium *Lyngbya majuscula* have been recorded at sites on the Great Barrier Reef. It is a high level irritant to humans, and damaging to both fishing and tourism industries, as well as to the ecosystem.[74] Marine turtles are known to consume the toxic cyanobacterium in the wild, exposing themselves to tumour-promoting compounds produced by this cyanobacterium.[75] Outbreaks of 'golden noodle' algae at a number of reefs[76] appeared to be linked to previous disturbance by crown-of-thorns starfish or bleaching. There is

Success in controlling crown-of-thorns starfish outbreaks

Col McKenzie, Executive Director of the **Association of Marine Park Tourism Operators**, has managed a joint industry and government program to control crown-of-thorns starfish outbreaks at tourism sites:

> *"The crown-of-thorns starfish control program has seen high use tourism sites protected from crown-of-thorns outbreaks, resulting in good coral cover and protection of some of the Reef's social and economic values. Given the looming threat from climate change and water quality, this means our reefs are in a better position to adapt to changing environmental conditions and we can continue to provide a world's best tourism experience. The program is a successful example of industry and government working together in partnership."*

also evidence that blooms of the free-floating algae *Trichodesmium*, although a natural phenomenon, may have increased since early scientific expeditions in the 1920s.[77] Such long-term changes are very difficult to evaluate due to the lack of quantitative information. Dramatic increases of native species, such as algal blooms, may indicate the ecosystem is under increasing pressure. The small gastropod snail *Drupella* occurs on the Great Barrier Reef but has not formed major outbreaks as it has in the Ningaloo reefs of Western Australia.[78] An outbreak of *Drupella* is considered to be occurring when they are at a density of about six individuals per square metre.[79]



Trichodesmium algae bloom

A red and black anemone fish lives in symbiosis with it's host anemone.

3.6 Assessment summary – Ecosystem health

Section 54(3)(a) of the *Great Barrier Reef Marine Park Act 1975* requires "*...an assessment of the current health of the ecosystem within the Great Barrier Reef Region and of the ecosystem outside that region to the extent that it affects that region*". This assessment is based on four assessment criteria:

- physical processes
- chemical processes
- ecological processes
- outbreaks of diseases, introduced species and pest species.

3.6.1 Physical processes

Assessment component	Summary	Assessment Grade: Very good	Good	Poor	Very poor
Ocean currents	Ocean currents vary naturally and there is insufficient evidence to know if patterns are changing in the Great Barrier Reef.	?			
Cyclones and wind	There is no evidence of more frequent cyclones but there is evidence of increased intensity.		●		
Freshwater inflow	Freshwater flows may be affected by drainage patterns in the catchment.		●		
Sedimentation	Exposure of the Great Barrier Reef to terrestrial sediments has increased, especially in inshore areas.			●	
Sea level	Sea levels have risen in the Great Barrier Reef and are projected to rise further.		●		
Sea temperature	Average water temperature across the Great Barrier Reef is increasing.			●	
Light	Increased sedimentation may be altering light levels in inshore areas.		?		
Physical processes	The physical processes of the Great Barrier Reef are changing, in particular sedimentation and sea temperature. Further changes in factors such as sea temperature, sea level and sedimentation are expected because of climate change and catchment runoff.		●		

GRADING STATEMENTS

Very good - There is no evidence of significant changes in physical processes.

Good - Some physical processes have changed in some areas, but not to the extent that the changes are significantly affecting ecosystem function.

Poor - Physical processes have changed substantially in some areas to the extent that ecosystem function is significantly affected in some parts of the Region.

Very poor - Physical processes have changed substantially and over a wide area. Ecosystem function is seriously affected in much of the Region.

3.6.2 Chemical processes

Assessment component	Summary	Assessment Grade: Very good	Good	Poor	Very poor
Nutrient cycling	Exposure to nutrients has increased for much of the Great Barrier Reef especially in inshore areas.			●	
Pesticide accumulation	There are traces of pesticides in the Great Barrier Reef environment, the impacts of which are largely unknown.			?	
Ocean acidity	The world's oceans are becoming more acidic affecting the growth of corals.		●		

Assessment component	Summary	Very good	Good	Poor	Very poor
Ocean salinity	The salinity of Great Barrier Reef waters is generally stable, with local short-term fluctuations after flood events, mostly close to the coast.	●			
Chemical processes	For much of the Great Barrier Reef, the chemical environment has deteriorated significantly, especially inshore close to developed areas. This trend is expected to continue. Acidification of all Great Barrier Reef waters as a result of increased concentrations of atmospheric carbon dioxide is an emerging serious issue which is likely to worsen in the future.			◉	

GRADING STATEMENTS

Very good - There is no evidence of significant changes in chemical processes.

Good - Some chemical processes have changed in some areas, but not to the extent that the changes are significantly affecting ecosystem function.

Poor - Chemical processes have changed substantially in some areas to the extent that ecosystem function is significantly affected in some parts of the Region.

Very poor - Chemical processes have changed substantially and over a wide area. Ecosystem function is seriously affected in much of the Region.

3.6.3 Ecological processes

Assessment component	Summary	Very good	Good	Poor	Very poor
Microbial processes	Changes in the physical and chemical environment are likely to be causing changes in microbial processes, but there is little information available.		?		
Particle feeding	Most populations of particle feeders are healthy although sea cucumbers are at risk to local depletion.		●		
Primary production	There is insufficient evidence to know if patterns of primary production are changing.	?			
Herbivory	Populations of herbivorous fish are healthy and generally not under pressure; however larger herbivores, like dugongs, have declined along the urban coast.		●		
Predation	Most predator populations are relatively healthy but a few species are under serious pressure, with potential flow-on impacts.			?	
Symbiosis	Little is known about most symbiotic relationships.		?		
Reef building	The rate of reef building may be beginning to slow.		●		
Competition	Competition between corals and algae appears normal except for some inshore areas, but there is little information about other types of competition.		?		
Connectivity	Most species and habitats remain adequately connected; connectivity between marine habitats and adjacent freshwater habitats has been reduced.		?		
Ecological processes	Most ecological processes remain intact and healthy on the Great Barrier Reef, but further declines in physical and chemical processes are expected to affect them in the future. There is concern for predation, as predators are much reduced in many areas. Populations of large herbivores (such as dugongs) are severely reduced, however populations of herbivorous fish remain intact.		◉		

GRADING STATEMENTS

Very good - There is no evidence of significant change in ecological processes.

Good - Some ecological processes have changed in some areas, but not to the extent that the changes are significantly affecting ecosystem function.

Poor - Ecological processes have changed substantially in some areas to the extent that ecosystem function is significantly affected in some parts of the Region.

Very poor - Ecological processes have changed substantially and over a wide area. Ecosystem function is seriously affected in much of the Region.

3.6.4 Outbreaks of disease, introduced species and pest species

Assessment component	Summary	Assessment Grade: Very good	Good	Poor	Very poor
Outbreaks of disease	The incidence of coral disease may be increasing in some areas.		○		
Crown-of-thorns starfish outbreaks	It appears that human impacts have increased the frequency and severity of crown-of-thorns starfish outbreaks.			○	
Introduced species	The occurrence of introduced marine species adjacent to the Great Barrier Reef Region is increasing.		○		
Other outbreaks	Outbreaks of other species, such as algal blooms, may indicate the ecosystem is under increasing pressure.		○		
Outbreaks of disease, introduced species and pest species	Outbreaks of diseases appear to be becoming more frequent and more serious on the Great Barrier Reef. Outbreaks of pest species appear to be above natural levels in some areas.			○	

GRADING STATEMENTS

Very good - No records of diseases above expected natural levels; no introduced species recorded; pests populations within naturally expected levels.

Good - Disease occasionally above expected natural levels but recovery prompt; any occurrences of introduced species successfully addressed; pests sometimes present above natural levels with limited effects on ecosystem function.

Poor - Unnaturally high levels of disease regularly recorded in some areas; occurrences of introduced species require significant intervention; pests in some areas affecting ecosystem function more than expected under natural conditions.

Very poor - Unnaturally high levels of disease often recorded in many areas; uncontrollable outbreaks of introduced pests; opportunistic pests seriously affecting ecosystem function in many areas.

3.6.5 Overall summary of ecosystem health

Many of the key processes of the Great Barrier Reef ecosystem are changing and this is negatively affecting the health of the ecosystem.

Increased sedimentation and inputs of nutrients and pesticides to the ecosystem are affecting inshore areas, causing algal blooms and pollutants to accumulate in sediments and marine species, reducing light and smothering corals. Sea temperatures are increasing because of climate change, leading to mass bleaching of corals, and increasing ocean acidity is affecting rates of calcification. These processes combined are essential to the fundamental ecological processes of primary production and building coral reef habitats on the Great Barrier Reef.

It is considered that the overall food web of the Great Barrier Reef is being affected by declines in herbivory in inshore habitats because the urban coast dugong population is a fraction of its former population; in predation on reef habitats because of potential reef-wide differences in coral trout and shark numbers on reefs open and closed to fishing; and in particle feeding on reef habitats because of the reduction in at least one species of sea cucumber.

Combined with more frequent outbreaks of disease and pests and changes in other physical, chemical and ecological processes, declines in these processes mean that the health of the Great Barrier Reef ecosystem is reduced.

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COMMERCIAL AND NON-COMMERCIAL USE

CHAPTER FOUR

"Beginning with the latent resources of .....the Barrier's – marvellous fish-fauna, they present almost unlimited possibilities of profitable development."

W. Saville-Kent, 1893
Biologist, businessman and pioneer fisheries manager

' an assessment of the commercial and non-commercial use …' of the Great Barrier Reef Region, Section 54(3)(c) of the *Great Barrier Reef Marine Park Act 1975*.

4 COMMERCIAL AND NON-COMMERCIAL USE

4.1 Background

The Great Barrier Reef supports a range of uses, both commercial and non-commercial.

Starting with the Traditional Owners thousands of years ago, the Great Barrier Reef has long been an important resource and a valued place for people to visit, share and enjoy.

For more than 30 years, the Great Barrier Reef Marine Park has been a multiple use area, providing protection, ecologically sustainable use, understanding and enjoyment. In managing the ecosystem, environmental, economic and social benefits and impacts are all considered in pursuing the best outcomes for both the Great Barrier Reef and the community.

The Great Barrier Reef supports significant commercial industries, especially commercial marine tourism and fishing (table 4.1) and supports employment equal to over 54 000 full-time positions. At the same time, shipping activity through the Great Barrier Reef is a vital link in the production chain for many industries and services regional centres. Importantly, use of the Great Barrier Reef Region goes well beyond commercial activities. It is central to the culture of Traditional Owners, a major recreational area, an internationally important scientific resource and an important area for defence training (figure 4.1).

Table 4.1 Direct plus indirect value added contributions of selected activities in the Great Barrier Reef catchment, 2006/07[1]

In 2006/07, Great Barrier Reef industries directly and indirectly contributed an estimated $5.4 billion to the Australian economy. The value for tourism includes activity in both the Great Barrier Reef and its catchment. Value added refers to the output after deducting the value of inputs.

Activity (value added)	($million)
Tourism	$5117
Commercial fishing	$139
Recreational use (including fishing)	$153
Total contribution	$5409

Use of the Region is an important component of coastal communities.

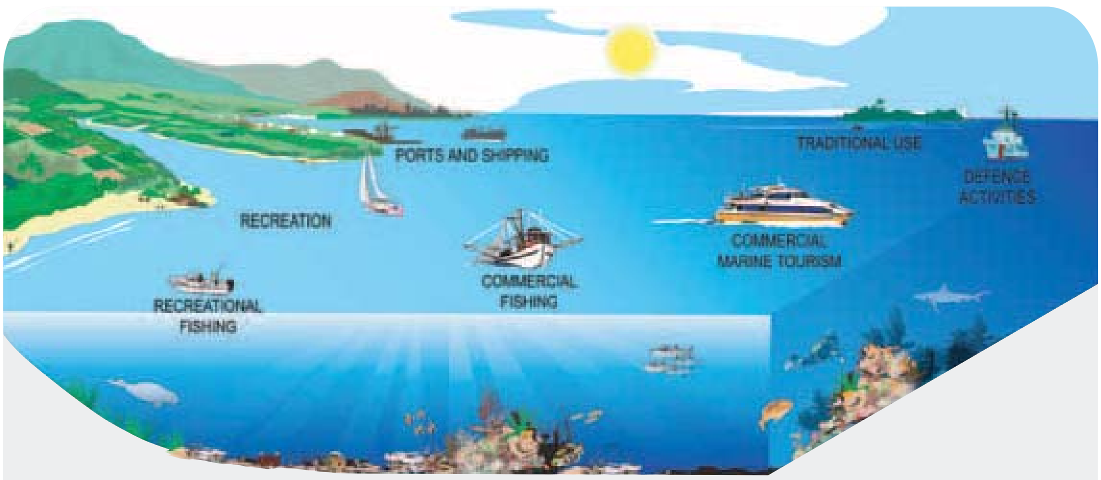


Figure 4.1 Uses of the Great Barrier Reef

The Great Barrier Reef ecosystem benefits many industries and the community.

Oil drilling, mining and exploration have been prohibited in the Great Barrier Reef Region since proclamation of the *Great Barrier Reef Marine Park Act* in 1975.

The Great Barrier Reef is valued by millions of people in Australia and around the world simply because it exists, even if they may never have the opportunity to visit it or derive an income from it (figure 4.2).

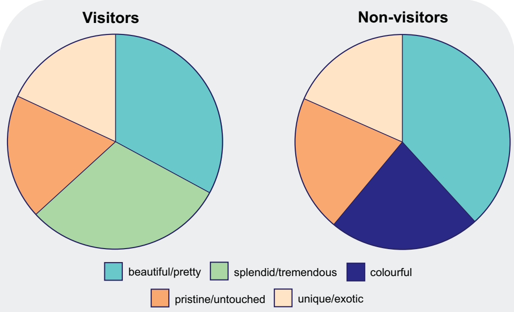


Figure 4.2 **Perceptions of the Great Barrier Reef**[2]

When describing the Great Barrier Reef there is little difference in comments by visitors and non-visitors. Both see the Great Barrier Reef as a beautiful and unique place.

A wide range of tourism experiences are offered in the Great Barrier Reef Region.

This assessment of commercial and non-commercial use examines the current state and trends of the major uses of the Great Barrier Reef Region and their associated benefits and impacts. The uses examined are:

- commercial marine tourism
- defence activities
- fishing
- ports and shipping
- recreation (not including fishing)
- scientific research
- traditional use of marine resources.

The evidence provided in this assessment also forms the basis for the assessment of direct use as a factor influencing the Reef's values (Section 5.5). Commercial and non-commercial uses occurring outside the Region that may indirectly affect the Great Barrier Reef ecosystem are considered in Chapter 5.

4.2 Commercial marine tourism

4.2.1 Current state and trends of commercial marine tourism

Begun in the 1890s, commercial marine tourism is now a major commercial use of the Great Barrier Reef. It offers a wide range of visitor experiences, ranging from cruise ships and live-aboard vessels to day trips on high speed catamarans and kayaking tours. Almost all these experiences are nature-based and reliant on an intact Great Barrier Reef ecosystem.

Almost all marine tourism is nature-based and relies on an intact Great Barrier Reef.

Collection of comprehensive information about tourist numbers and locations visited began in July 1993 with the introduction of the Environmental Management Charge – a charge for tourism operations, based on the number of both full and part day visitors carried. In 2008, a total of 1 895 428 tourism visits were made to the Great Barrier Reef Marine Park of which 1 374 008 were full day visits and 521 420 were half day visits or visitors who did not pay the Environmental Management Charge (figure 4.3). In the same year, an additional almost 3 000 000 people were transported by the tourism fleet to visit island destinations throughout the Region.

Around two million tourists visit the Great Barrier Reef each year.

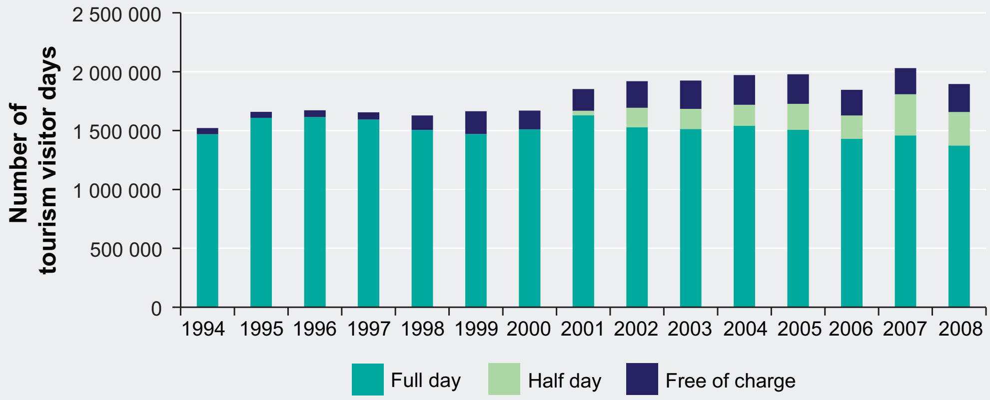


Figure 4.3 Number of tourism visitor days to the Great Barrier Reef Marine Park, 1994–2008[3]

Tourism visits to the Great Barrier Reef have been relatively stable for the last decade. A 'visitor day' is a visit by one tourist on one day. For longer visits, each day is counted separately (e.g. a three-day visit by a tourist represents three visitor days). A half day visit refers to visitors who undertake a trip of less than three hours, and free of charge visitors include young children and trade familiarisations. Ongoing improvement in the way Environmental Management Charge information is recorded has allowed more accurate differentiation of these latter two charges.

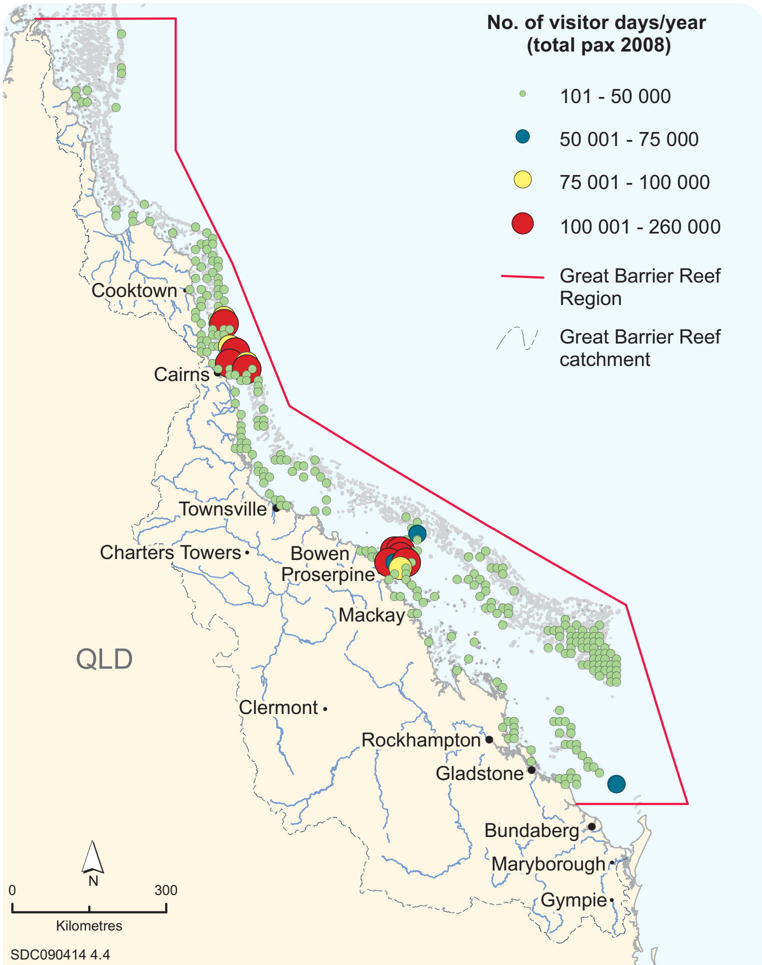


Figure 4.4 Distribution of tourism activity across the Great Barrier Reef, 2008[3]

Tourism use of the Great Barrier Reef is strongly focused on the areas offshore from Cairns and Port Douglas and around the Whitsunday islands and adjacent reefs.

Tourism activity in the Great Barrier Reef is consistently focused in a small portion of the Region with about 80 per cent of all tourism activity occurring in about seven per cent of the Region (figure 4.4). In 2008 about 44 per cent of the full day visits took place at locations offshore from Cairns and Port Douglas and another 43 per cent were around the Whitsunday islands and adjacent reefs (offshore from Proserpine).

Many global factors influence tourism visitation to the Great Barrier Reef Region. Threats to safety, concern about disease epidemics, currency values, concern over carbon emissions from long haul flights and economic conditions can significantly affect the number of international visitors choosing to visit Australia and in turn the Great Barrier Reef (figure 4.5). Flight schedules and airline seating capacity into Great Barrier Reef tourism centres (e.g. Cairns and the Whitsunday region) also directly affect the number of visitors to the Region. Currently around 60 per cent of tourists to the Great Barrier Reef come from international destinations.[4]

Management The conduct of all tourism operations is closely managed in the Great Barrier Reef, focusing on the areas of highest use and sensitivity. Under the *Great Barrier Reef Marine Park Zoning Plan 2003*, commercial marine tourism may be conducted in almost all zones and localities of the Great Barrier Reef Marine Park so long as a

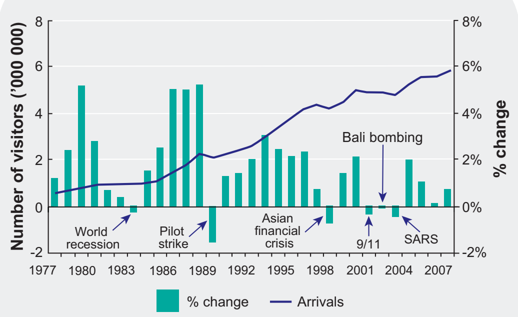


Figure 4.5 The influence of international events on overseas visits to Australia[5]

Often factors well beyond the control of the tourism industry affect how many visitors choose to visit Australia. This in turn affects numbers visiting the Great Barrier Reef.

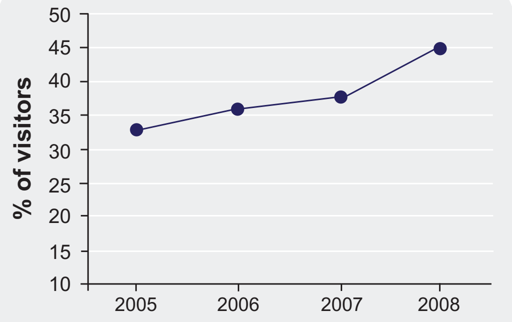


Figure 4.6 Proportion of tourists visiting the Great Barrier Reef on a certified high standard tourism operation[3]

More than four in every 10 tourists are now experiencing the Great Barrier Reef with a certified high standard operator recognised by the independent Eco Certification Program. This voluntary program, introduced in 2005, is additional to the mandatory management arrangements for tourism operations.

Marine Parks permit has been obtained. Statutory Plans of Management for the Cairns Area, Hinchinbrook and the Whitsundays set out more detailed tourism management arrangements, including capping some permit types and defining maximum group and vessel sizes in individual locations. Site management arrangements and specific policies also apply to tourism operations.

As at April 2009, there were 958 current Marine Parks permissions to conduct a tourism operation on the Great Barrier Reef, of which over 500 were actively used.[3] However, many of these are small-scale operations that carry only small numbers of tourists (e.g. less than 10 people) or operate infrequently (e.g. less than 50 days per year). In 2008, 50 operators carried almost three-quarters of the tourism visitor days.[3]

In addition to the mandatory management arrangements for commercial marine tourism in the Great Barrier Reef, tourism operators have the opportunity to demonstrate the achievement of best practice environmental, economic and social standards in their operations by becoming independently certified with the Eco Certification Program[6], managed by Ecotourism Australia. There are 80 reef-based tourism products operated by 44 different tourism operators (including most of the larger operators) that are certified as operating to high standards. This results in 45 per cent of commercial tourists visiting the Great Barrier Reef with Eco Certified operators (figure 4.6). In addition, almost one-quarter of these certified high standard operators have been Climate Action Certified by Ecotourism Australia.

4.2.2 Benefits of commercial marine tourism

In the 2006/07 financial year, tourism throughout the Great Barrier Reef and catchment was the largest direct contributor to economic activity when compared to other reef-based industries. It made a direct and indirect contribution of $5.1 billion to the Australian economy (table 4.1).

In the 2006/07 financial year, the Great Barrier Reef Region supported employment equal to 53 800 full-time positions throughout Australia, with 93.5 per cent of these directly or indirectly involved in tourism. Within the Great Barrier Reef catchment area the equivalent of 39 700 full-time positions across all industries were derived from the Great Barrier Reef, 92.7 per cent of these were employed in tourism.[1]

Tourism makes a significant contribution to the presentation, management and economic value of the Great Barrier Reef.

The tourism industry is seen as a key partner in protection and management of the Great Barrier Reef. As well as permit fees paid by operators, the tourism industry collects about $7 million each year from tourists through the Environmental Management Charge (figure 4.7). These funds directly contribute to management of the Great Barrier Reef.

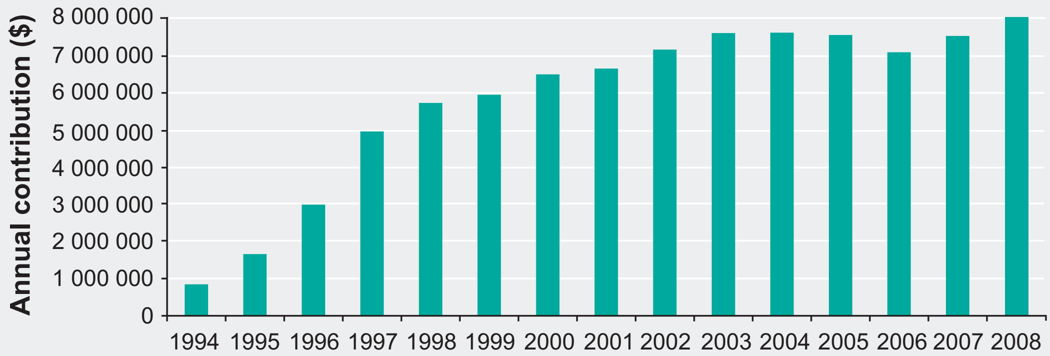
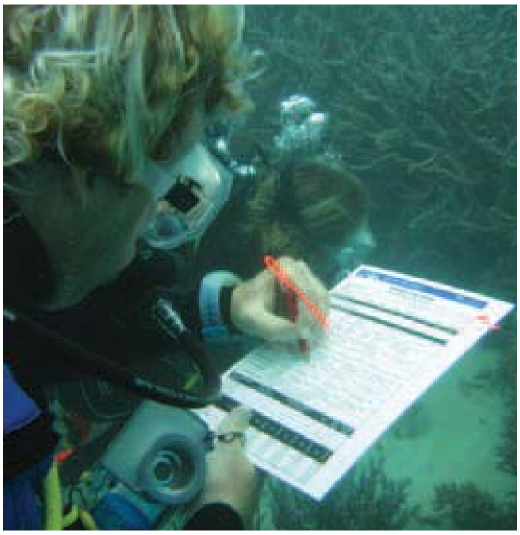


Figure 4.7 **Financial contributions received from the Environmental Management Charge, 1994-2008[3]**

The tourism industry collects from tourists an Environmental Management Charge based on the number of tourists carried. These funds are directed to research and management of the Great Barrier Reef. (The value of the charge for a full day visitor has increased from $1 in 1994 to $5 in 2008). Years indicate the end of the relevant financial year.

In addition, many operators contribute to the overall management and understanding of the Great Barrier Reef ecosystem by participating in research and reporting programs such as the Eye on the Reef environmental monitoring program, BleachWatch, the Sightings Network, and visitor surveys. These programs help collect information about reef condition, environmental and social variables and ecological events at a variety of locations throughout the Great Barrier Reef.



Tourism operator staff contributing to the Eye on the Reef program.

Education and interpretation is a component of most tourism programs in the Great Barrier Reef – focusing on not only its natural environment, but also the sustainable practices that support the Great Barrier Reef both during a visit and at home. This helps raise awareness of the Great Barrier Reef, its protection and management.

Importantly, the tourism industry provides an additional benefit in terms of making the vast area of the Great Barrier Reef accessible to visitors. Without the fleet of tourism vessels and aircraft that visit the Great Barrier Reef daily, many sightseers simply could not access it. In this way, the tourism industry presents the Region's World Heritage values to the public.

4.2.3 Impacts of commercial marine tourism

Concern about the impact of tourism in the Great Barrier Reef arose during the early 1990s with widely reported damage from anchoring and impacts on adjacent islands; predictions of increasing impacts of use (such as damage to coral and sewage discharge) and forecasts of exponential growth in tourism numbers. There is now a range of mandatory and voluntary management arrangements that minimise the impact of commercial tourism operations in the Great Barrier Reef, such that the impacts associated with tourism activities are seen as minor[7] (see also Chapter 8).

Detailed assessments[8] have found that the operation of permanently moored tourism pontoons and associated activities such as fish-feeding have had minimal impacts on the surrounding reef.

Success in reducing tourism impacts

Tony Baker, Chairman of the **Association of Marine Park Tourism Operators**, has worked in the Great Barrier Reef tourism industry for many years. He comments on improvements in tourism operating standards:

> *"The Great Barrier Reef tourism industry recognises that a healthy tourism industry relies on a healthy Great Barrier Reef, and that we all have a role to play in minimising our impact on the Great Barrier Reef. I am very proud of the number of companies that are achieving high environmental standards and of all the contributions that marine tourism operators have made to reduce their 'footprint' on the Reef environment - from installing moorings and intensive client briefings to monitoring for crown-of-thorns and coral bleaching. Today's tourism industry is very proud of the Great Barrier Reef and is committed to its protection to ensure its enjoyment for future generations."*

Anchoring of tourism vessels has the potential to damage corals and seagrass habitats. The likelihood of anchor damage from tourism activities has been reduced by the installation of public and private moorings in high use areas, designated anchoring and no anchoring areas, Reef Protection Markers and best practices guidelines. At the end of 2008 there were 757 private moorings[9] and 128 public moorings[10] in the Great Barrier Reef Marine Park, concentrated in areas of highest use.

In some popular locations, Reef Protection Markers help protect coral reefs by delineating areas where anchoring is not allowed.

Diving and snorkelling can cause localised damage to coral, but are generally closely supervised.

To minimise impacts on coral reefs, sewage discharge by all users, including tourism operations, is only allowed in open waters (more than one nautical mile from any reef, island, mainland or aquaculture facility). Discharge at sea remains necessary as there are insufficient land-based facilities to service the pump-out requirements of the tourism fleet. Total sewage discharge into the Marine Park accounts for only three per cent[11] of the entire nutrient load (see Section 5.4), and tourism vessels contribute only a small portion of this total.

Marine tourism extends throughout the Great Barrier Reef but its impacts are concentrated in a few intensively managed areas.

4.3 Defence activities

4.3.1 Current state and trends of defence activities

The Great Barrier Reef is a critical part of Australia's defence training programs. Intensive training activities are regularly undertaken in a few designated areas of the Great Barrier Reef, which cover less than four per cent of the Great Barrier Reef Marine Park. While most of these areas are small, the Shoalwater Bay Military Training Area is one of Australia's largest. Activities include navy clearance dive training, boating and navigation exercises as well as amphibious landings.[12] This use may increase over time.[12]

Management All defence training activities are managed directly by the Australian Department of Defence. There are six major areas of defence activity (figure 4.8). Management of the environmental impacts of defence training within the Great Barrier Reef Marine Park is undertaken by the Department of Defence in collaboration with the Great Barrier Reef Marine Park Authority, the Australian Department of the Environment, Water, Heritage and the Arts and the Queensland Department of Environment and Resource Management.

The Department of Defence has a moratorium on the use of high explosives in the Great Barrier Reef World Heritage Area except in the Shoalwater Bay training area. Many defence activities are conducted with dedicated shipboard and aerial observers. These personnel are able to collect data on marine wildlife sightings, as well as ensure activities are delayed if required.

4.3.2 Benefits of defence activities

Defence activities in the Great Barrier Reef directly contribute to the training and operations of Australia's defence services.

The majority of routine defence training activities have negligible impacts.

4.3.3 Impacts of defence activities

Most of the routine defence training activities carried out in the Great Barrier Reef have negligible impacts. Comprehensive assessment and management means that the impacts of major exercises are minimised as far as possible. Individual high impact activities are carefully managed and confined to specific localised areas, and limited to a few weeks per year.[12]

Figure 4.8 **Designated defence areas in the Great Barrier Reef**[13]

There are six designated defence areas within the Great Barrier Reef Region.

4.4 Fishing

4.4.1 Current state and trends of fishing

The Great Barrier Reef supports commercial, recreational, Indigenous and charter fishing, targeting a range of species including fish, sharks, crabs and prawns.

There are 10 major commercial fisheries in the Great Barrier Reef Region (table 4.2). The main commercial sectors are the net, trawl, line and pot fisheries. Commercial fishing is limited entry and is spread across the Great Barrier Reef (figure 4.9). The commercial fishing industry of the Great Barrier Reef is important to both domestic and international markets. For example, although exact figures are not known, a substantial proportion of the commercial live trout trade into Hong Kong comes from the Great Barrier Reef.

Recreational fishing is an open access fishery, taking an estimated six million fish in 2007 (table 4.2). Recreational effort is mostly focused in inshore areas. While the Great Barrier Reef coastal population has been rapidly increasing in recent years, surveys suggest that the proportion of coastal residents who fished within the preceding 12 months decreased from 39 per cent in 2001 to 20 per cent in 2005 and 15 per cent in 2007.[14] There is insufficient information to determine whether this decline in participation is matched by a decline in total catch.

Estimates of the total take of fish by recreational fishers is at present limited to Queensland-wide estimates derived from telephone surveys, the last being conducted in 2005.[15] A minority of skilled and devoted recreational fishers are thought to take the majority of recreational catch, although exact ratios are not known.

Indigenous and charter fishers also operate in the Region, but their activity accounts for a relatively small component of the overall fisheries take and there is little information available. Fishing by Traditional Owners is considered further in Section 4.8.

There has been limited, mostly research focused, marine-based aquaculture within the Great Barrier Reef, but extensive land-based aquaculture in the catchment (see Section 5.4).

Global fisheries trends influence those of the Great Barrier Reef. As wild-caught fisheries throughout the world continue to be fully exploited or over exploited[17], the economic value of Great Barrier Reef fisheries resources and the pressure to exploit them (legally and illegally) may increase. International demand for wild caught Queensland seafood may increase the targeting of additional species or increase calls to allow intensive aquaculture both within the Great Barrier Reef Region and its catchment. Expected significant increases in aquaculture around the world (for example aquaculture-raised coral trout are expected to be commercially viable in the near future)[17] may also lead to diversification in the reef line fishery and increased targeting of other species.

Of increasing significance are changes in the price of fuel (figure 4.10), which affects profitability and in some cases methods and places of operation. Some fishing operators report altering their usual fishing patterns to minimise fuel consumption.

The Great Barrier Reef supports a wide variety of fishing activities.

Table 4.2 **Fisheries of the Great Barrier Reef, 2007**[16]

The Great Barrier Reef supports a diversity of fisheries and is a major part of Queensland's fishing activity. It includes commercial and recreational fisheries, plus some charter and Indigenous fishing.

Fishery	No. of primary licences issued (Qld)	Est. proportion of Qld fishery within Great Barrier Reef	Retained catch in the Great Barrier Reef, 2007	Main target species
Coral	59	99%	~110 tonnes	'Live rock' and potentially hundreds of species of hard and soft corals, zooanthids, corallomorphs etc
Line	1531	Reef=~95% Inshore=~50%	1676 tonnes	Reef: coral trouts, cods, emperors and snappers, Spanish mackerel Inshore: barramundi, shark, mackerel, cobia, pelagics
Marine aquarium fish	49	~60%	~56,000 fish, mostly juveniles	Potentially hundreds of species but mostly Pomacentrids, Labrids, and Pomacanthids
Net	500	~40%	2039 tonnes	Barramundi, shark, mackerel, threadfin salmon, bait species
Pot	845	~65%	541 tonnes	Mud crab, blue swimmer crabs and three-spot crabs
Recreational	N/A	40%	~6 million fish (2005 data)	Coral trouts and cods, emperors, tropical snappers, barramundi, bream, mackerels, whiting, flathead, threadfin salmon, trevally, shark, mud/blue swimmer crabs, lobster, bait
Sea cucumber	18	100%	284 tonnes	Sea cucumbers (mainly white teatfish & burrowing blackfish)
Spanner crab	507	<20%	525 tonnes	Spanner crabs
Trawl (otter)	460	~57%	3328 tonnes	Prawns, scallops, Moreton Bay bugs, squid
Trochus	6	100%	109 tonnes	Large herbivorous gastropod *Trochus niloticus*
Tropical rock lobster	28	100%	235 tonnes	Ornate rock lobster *Panulirus ornatus*

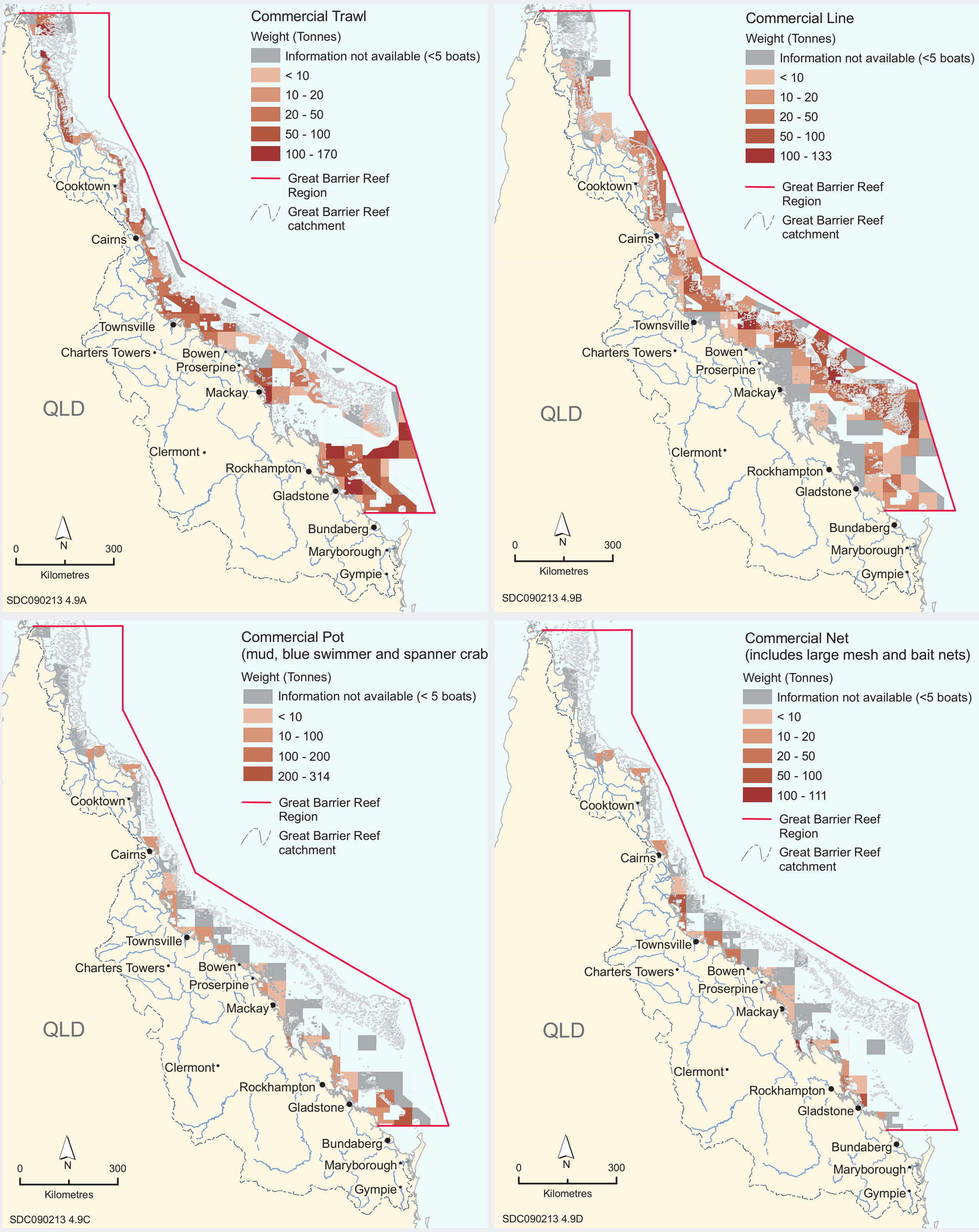


Figure 4.9 **Spatial distribution of catch by commercial trawl, line, pot and net fisheries, Great Barrier Reef, 2007**[15]

The amount of fisheries product taken from different areas in the Great Barrier Reef varies for each of the major fisheries. Net and pot fisheries are undertaken close to the coast whereas trawling and line fishing extend further offshore. The tonnages shown are for each fisheries "grid" (a 30 nautical mile^2 area), with the zones closed to fishing excluded.

External pressures on the commercial trawling fleet

Gary Wicks is a trawl fisher from Cairns who is a representative on the **Queensland Seafood Industry Association** (QSIA) Trawl Committee, and also sits on the QSIA Board and a number of advisory committees. Gary has fished the east coast of Queensland and the Gulf of Carpentaria for 35 years.

"Over the last decade, a range of management measures, together with licence buyouts, have significantly reduced the trawl fleet and changed where and how it operates in the Great Barrier Reef Marine Park... On top of this, a number of local and global economic drivers such as cost of fuel, poor exchange rate, cheap imported products and issues with the local labour market have also dramatically reshaped the fleet. Even four years ago we would have seen at least 300 trawlers travelling through the Marine Park to work from Mackay to Cape York each season but last year (2008), the numbers were down to just a hundred or so."

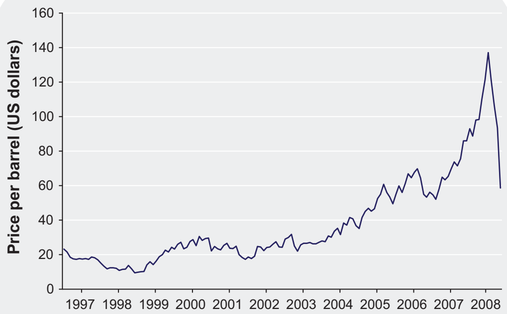


Figure 4.10 **Changes in international crude oil prices**[18]

The price of fuel has increased rapidly in recent years, with an unprecedented peak in mid-2008. Crude oil prices track very closely with diesel prices.[19]

Management Direct management of fishing activities in the Great Barrier Reef (for example licences, fish size and possession limits and seasonal closures) is the responsibility of the Queensland Government. For the commercial fisheries, licences (and, in some cases, Marine Parks permits) are required by all operators. Recreational fishing is subject to size and possession limits.

The *Great Barrier Reef Marine Park Zoning Plan 2003* applies to all fishing activities and results in about 67 per cent of the Great Barrier Reef Marine Park being available for various types of fishing.

4.4.2 Benefits of fishing

Product taken in the Great Barrier Reef Region is an important component of the Queensland seafood industry, with about 95 per cent of the reef line fishery, 60 per cent of the trawl fishery, 40 per cent of the net fishery and 40 per cent of recreational fishing taking place in the Great Barrier Reef Region (table 4.2).

Fishing provides opportunities for recreation, resources for the seafood industry, and generates regional economic value.

In the 2006/07 financial year, commercial fishing in the waters of the Great Barrier Reef Region contributed $139 million to the Australian economy and recreational use (including recreational fishing) contributed $153 million (table 4.1).

Commercial fishers pay an annual fee to the Queensland Government for their licence, but the specific amount collected for the Great Barrier Reef component is unknown. Recreational fishers pay an annual fee to the Queensland Government to register their vessels.

For many decades, fishing on the Great Barrier Reef has been an important cultural activity for coastal residents and visitors, with most people indicating that their reasons for recreational fishing were relaxation, socialising, catching fish and excitement.[20] In 2008, more than half of all people visiting the Great Barrier Reef for recreation went fishing (figure 4.22).

Increasing awareness of the need for environmental stewardship has prompted some recent initiatives amongst some commercial and recreational fishing sectors to develop best practice. There is increasing participation by fishers in various monitoring programs such as BleachWatch and specific research projects.

4.4.3 Impacts of fishing

For every one tonne of fisheries catch retained, there are almost two tonnes not retained.

The combined retained and non-retained catch for commercial, recreational, charter and Indigenous fisheries is estimated to be about 38 000 tonnes of the Great Barrier Reef's resources each year (figure 4.11). Of this amount, retained catch from fishing is more than 14 000 tonnes each year. The remainder of the catch is returned to the sea, and the survival success of this non-retained catch is poorly understood.

About 55 to 60 species are targeted in commercial and recreational fishing. Almost all the commercially targeted species are top predators (e.g. sharks), predators (e.g. coral trout and mackerel) or particle feeders (e.g. prawns, crabs and scallops) (figure 4.12).

Annual status reports are produced for each major fishery.[16 21 22] Monitoring[23] and stock assessments[24] are completed for a limited number of target species, based on the potential risk of over fishing to the species. These reports and assessments have indicated that populations of some species are under pressure including grey mackerel, garfish, snapper and black teatfish (a sea cucumber).

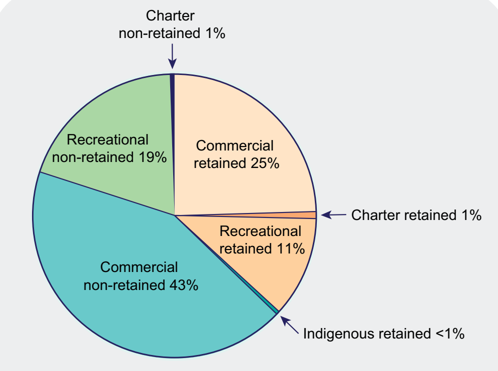


Figure 4.11 Retained and non-retained fisheries catch, Great Barrier Reef, 2007[15]

The retained catch of commercial fisheries is about twice that of the recreational retained catch. A high proportion of the 38 000 tonnes caught in the Great Barrier Reef each year is discarded.

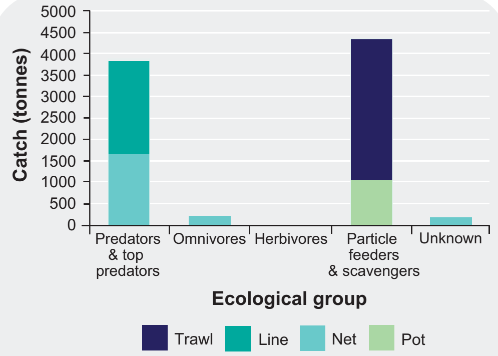


Figure 4.12 Ecological groups retained by commercial fishing, Great Barrier Reef, 2007[15]

Herbivores are not generally targeted on the Great Barrier Reef, most species caught are carnivores (top predators and predators) or particle feeders.

Success in improving understanding of recreational fishing

Bill Sawynok, Manager of CapReef, has been monitoring recreational fishing activities in southern areas of the Great Barrier Reef for four years. He recalls the progress that has been made:

> *"CapReef has received enormous support from the Capricorn Coast community. We collected details on 1279 offshore fishing trips for 2005/06. We determined that the total catch was 17 844 and that around 60.7 per cent of the fish caught were released. This information, combined with the two reports we released in 2006, provide reef managers with a great picture of the fishery in our area."*

A recent review of the proposed management arrangements for the East Coast Inshore Finfish Fishery highlighted the significant lack of data available to gauge sustainability and manage the fishery, the limited information on the species composition of shark catches, and the fact that these species are taken by other sectors.[25] Information is not available for many other species, including some of the shark species that are considered to be at moderate or high risk from fishing pressure.[26] Studies of coral trout have shown that while numbers are reduced, the populations are generally resilient and have rapidly recovered in no-take areas[27] (see Chapters 2 and 7).

The large amount of non-retained catch in the commercial sector (43 per cent of the total fisheries catch) results mainly from trawling activities (figure 4.13). Current management requirements, such as bycatch reduction devices, turtle excluder devices, effort reduction and specified target and retained species are addressing some of the most significant trawl bycatch issues.[28 29]

Recent management changes mean that fewer non-commercial species are captured in trawl nets.

Non-targeted catch (bycatch) in the commercial inshore net fishery includes a number of species of conservation concern that may be injured or killed in the nets (for example marine turtles, dugongs, dolphins, sharks and sawfish).[21 30 31 32] Mortalities within these species are of particular concern as some populations are already diminished[33] (see Section 2.3). For the commercial line and pot fisheries, discards are mostly undersized target species, no-take female crabs or the result of species preferences amongst fishers. Small marine turtles can drown in crab pots or may become entangled in pot float lines.[30]

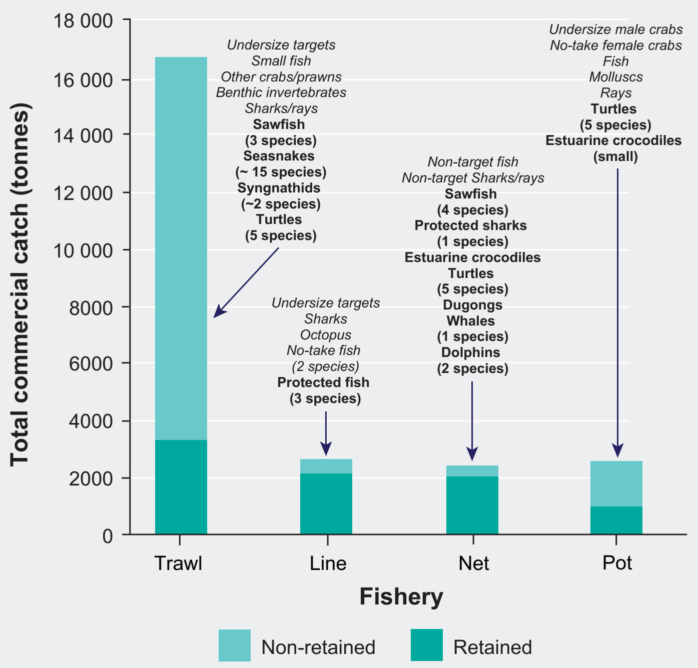


Figure 4.13 **A breakdown of commercial fisheries non-retained catch, Great Barrier Reef, 2007[34]**

Trawling is responsible for most of the commercial non-retained catch. The continuing interactions between the net fishery and species of conservation concern are of ecological concern. The species and groups of species listed in the figure are those most commonly caught but not retained. Species of conservation concern are in bold type. Syngnathids includes seahorses and pipefish.

Most of the non-retained (discarded) catch in recreational fishing is a result of size and possession limits, species preference and increasingly, a catch-and-release philosophy.

Most fishing techniques (for example line, net and pot) have little impact on habitats. However, trawling has the potential to cause habitat damage if not appropriately managed and damage to some of the more sensitive lagoon communities may have occurred in the past. Since the rezoning of the Great Barrier Reef Marine Park in 2004, trawling is allowed in 34 per cent of the Great Barrier Reef Region; however, it takes place in only about six per cent of this area each year (figure 4.14).

Ongoing habitat impacts in most regularly trawled areas are likely to be low as studies show these areas to be generally muddy, silty or sandy and likely to be regularly disturbed naturally.[36]

The survival success of discarded species is not well understood, but some species can be significantly affected.

Most fishing techniques have little impact on habitats; trawling is restricted to areas where it generally has minimal impact on the seabed.

Herbivorous fish are not targeted in almost all commercial and recreational fishing on the Great Barrier Reef (figure 4.12). This is important as herbivores play a key role in maintaining the ecological balance between algae and coral on reefs (Section 3.4).

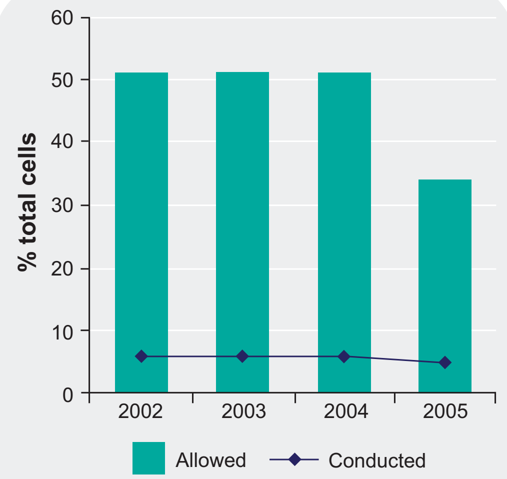


Figure 4.14 **Proportion of the Great Barrier Reef trawled, 2002-2005[35]**

About six per cent of fisheries 'cells' in the Great Barrier Reef are trawled more than once a year, where a cell equals one km². The bars show the percentage of cells where trawling is allowed in the Great Barrier Reef. The line shows the percentage of cells where trawling occurred more than once a year.

Ecosystem effects and cumulative impacts of fishing are poorly understood.

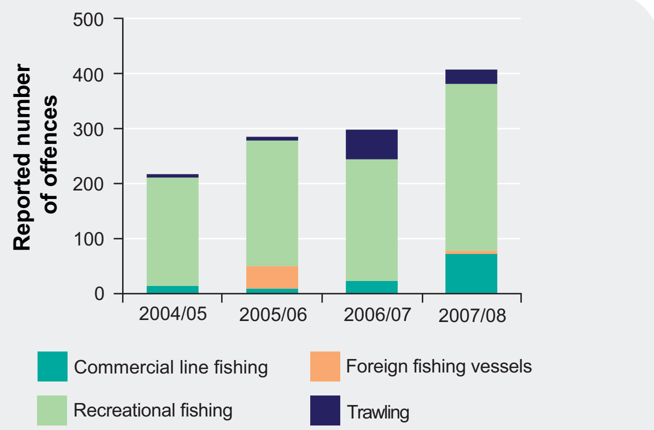
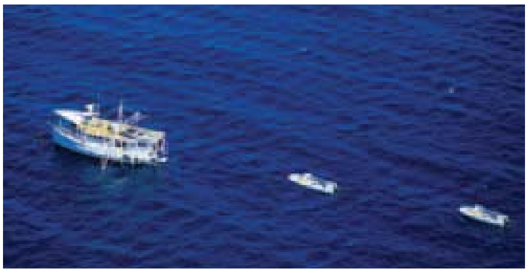


Figure 4.15 **Main reported domestic fishing and foreign incursion offences in the Great Barrier Reef, 2004-2008[37]**

Recreational, trawling and commercial line fishing offences are the most numerous domestic compliance issues in the Great Barrier Reef. Although netting offences are not frequently reported they are of considerable compliance concern due to the potential impact on species of conservation concern. Data is presented from 1 July 2004 when the *Great Barrier Reef Marine Park Zoning Plan 2003* came into effect.



Line fishing has little impact on the habitats of the Great Barrier Reef.

There are uncertainties about the complex broad scale and cumulative ecosystem effects of fishing. For example, scientific studies have shown that as well as affecting the abundance and characteristics (such as age and size) of targeted predator species in zones that are open to fishing, fishing may also affect their prey species (figure 3.17). Fishing may also have affected ecosystem function indirectly. For example, it appears that outbreaks of crown-of-thorns starfish are more likely in zones open to fishing (figure 3.18).

Illegal fishing is a threat to the Great Barrier Reef ecosystem. Incidents detected include the incursion of foreign fishing vessels, fishing in zones closed to fishing and use of fishing equipment or methods in zones where they are not permitted. In the 2007/08 financial year, there were 419 reported illegal fishing breaches of the *Great Barrier Reef Marine Park Zoning Plan 2003* and Regulations. Trends in illegal fishing activity are difficult to interpret as the number of incidents detected depends to some extent on the capacity of field management (figure 4.15). In some cases, a higher number of reported incidents have been a direct result of compliance activity and not necessarily a result of increased illegal activity.

Marine-based aquaculture There is currently only one commercial aquaculture operation within the Great Barrier Reef Region (barramundi farm in Hinchinbrook Channel); its environmental impact is very localised. In the past, pearl farms have operated in the Region. The predicted increase in demand for seafood products may result in demand for more aquaculture facilities within the Great Barrier Reef Region.

The impacts on the Great Barrier Reef of land-based aquaculture are considered in Section 5.4.

Shark Control Program Since 1962, the number of sharks around popular swimming beaches (between Cairns and the Gold Coast) has been controlled in an effort to reduce the risk to swimmers. Control measures have included the use of large mesh nets set parallel to beaches or baited drumlines. As well as impacting shark populations[38 39] nets have caught dugongs[31 40], inshore dolphins[32] and marine turtles (mostly green turtles) and drumlines have caught marine turtles (mostly loggerhead turtles).[30] Between 1962 and 1992, 837 dugongs were drowned in shark nets.[40] In most locations, nets have been replaced with drumlines, significantly reducing the impacts on marine mammal and marine turtle populations.[39] In the Great Barrier Reef Region 10 nets (five in Cairns and five in Mackay) and 171 drumlines remain.

4.5 Ports and shipping

4.5.1 Current state and trends of ports and shipping

There are 10 major trading ports along the Great Barrier Reef coast (figure 4.16). The waters of most of these ports are within the Great Barrier Reef Region, but not within the Great Barrier Reef Marine Park. Over 3500 ships operated in the Great Barrier Reef in 2007, making over 9700 voyages (figure 4.17). Over the last 10 years there has been a gradual increase in the number of voyages undertaken through the Great Barrier Reef Region, driven mainly by industrial and mining activity. Shipping cargo includes coal, sugar, iron ore, timber, oil, chemicals, live cattle and general cargo.

Global factors directly affect shipping activity, and in turn the ports that service it. The global economy also drives the need for product export. The amount of shipping in the Great Barrier Reef is, in part, a direct reflection of the global economy and development occurring overseas and the need for products to supply economic activity. Expansion in shipping and port activity is expected to continue (Chapter 5), although recent shifts in global economic activity are expected to slow growth.

Management In recognition of the outstanding values of the Great Barrier Reef, there are stringent management arrangements for commercial shipping in the waters of the Great Barrier Reef, which is designated a Particularly Sensitive Sea Area by the International Maritime Organisation.

Shipping traffic is confined to Designated Shipping Areas in the Great Barrier Reef Region (figure 4.16).

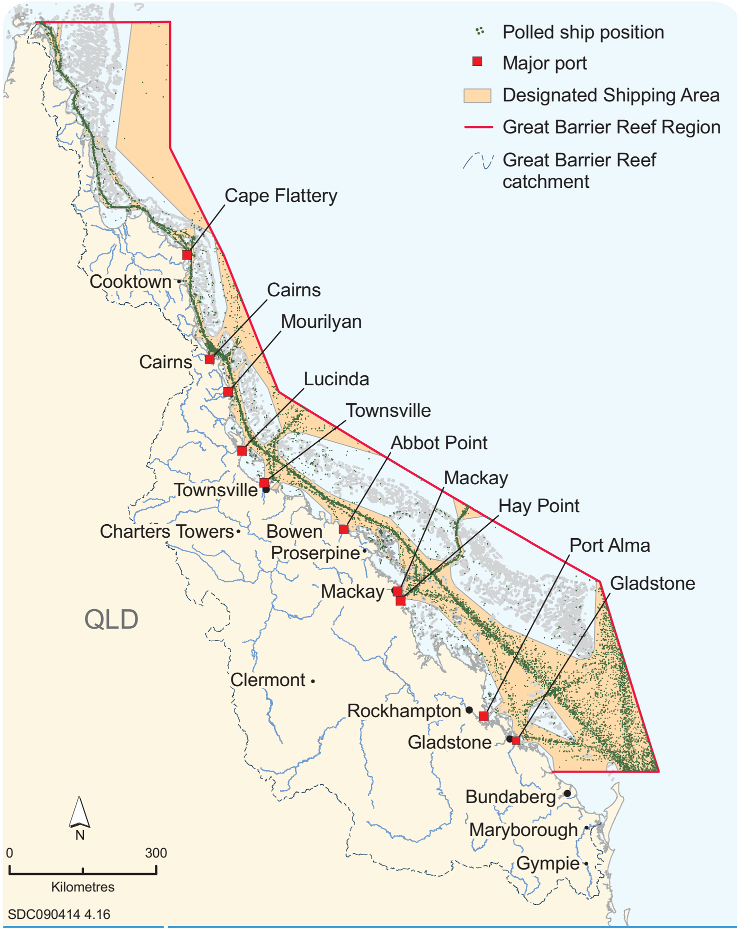


Figure 4.16 Major ports and shipping movements in the Great Barrier Reef, 2006[41]

There are 10 major ports along the coast. The inner shipping route of the Great Barrier Reef is a vital part of the Queensland shipping industry. The Designated Shipping Area is defined in the *Great Barrier Reef Marine Park Zoning Plan 2003*. Each polled ship position during 2006 is plotted as a green dot.

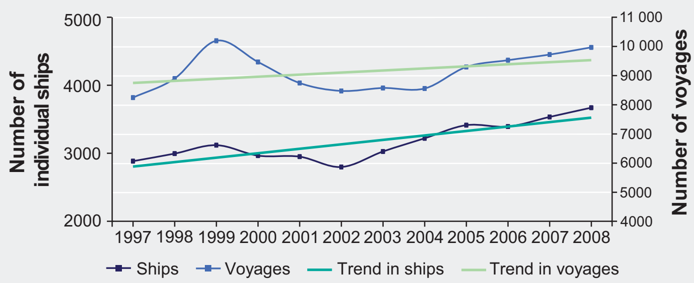


Figure 4.17 Shipping activity in the Great Barrier Reef, 1997–2008[41]

Over the last 10 years, shipping on the Great Barrier Reef has increased - both the number of voyages undertaken and the individual ships that operate in the Region. A voyage is defined as one passage through a section of the Great Barrier Reef.

Measures to increase navigational safety and reduce the risk of ship groundings and collisions include compulsory pilotage, recommended pilotage and mandatory vessel reporting and monitoring. Relevant management agencies also have incident response plans in place to respond to shipping events in the Region.

Most routine shipping activities have negligible consequences but there are significant potential risks, which are intensively managed.

All the adjacent ports of the Great Barrier Reef are managed by five Port Authorities, which are Queensland Government-owned corporations. Port activities are governed by local, state, national and international requirements for the protection of the environment from dredging and spoil disposal, waste, pollution and introduced marine pests.

4.5.2 Benefits of ports and shipping

The passage of ships through the Great Barrier Reef is essential to the economic viability of the major industries in the broader region and is important to the Queensland regional economies served by the ports. In addition, the ports of the Great Barrier Reef Region service the population of central and northern Queensland, providing them with food, fuels and consumer goods. The shipping industry that transits the waters of the Great Barrier Reef accounts for an estimated $17 billion of Australia's export trade each year.[42]

Dredging and constructing of ports can have significant, but localised impacts.

4.5.3 Impacts of ports and shipping

Shipping can potentially damage the Great Barrier Reef by collisions, groundings, introduction of invasive marine pests, oil and chemical spills, introduction of anti-fouling paints, waste disposal and anchor damage. Almost all ships travel safely along the designated shipping routes of the Great Barrier Reef with little if any impact. In the last 10 years there have been three or fewer major shipping incidents each year and, despite the increase in shipping traffic, the number of major incidents has been stable over that period (figure 4.18). Major incidents refer to incidents which require a significant response (usually collisions or groundings).

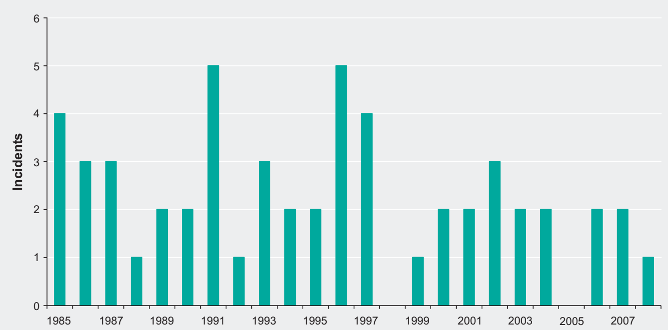


Figure 4.18 **Major shipping incidents in the Great Barrier Reef, 1985-2008[41]**

Improvements in shipping management have resulted in fewer major shipping incidents, despite an increase in traffic.

In addition to numerous minor oil spills, there has been only one major oil spill (25 000 litres) in the last 20 years in the Great Barrier Reef Region. The incident took place in Gladstone Harbour and most of the oil was recovered quickly. Of the remaining oil, most was entrained offshore and little was deposited on the coastline. There were local impacts to coastal species including mangroves, crabs and sediment-dwelling species. Recovery is being recorded as part of the ongoing environmental monitoring of the area.[43] In the early months of 2009, two major incidents involving oil spills occurred in waters adjacent to the Great Barrier Reef Region, one in the Torres Strait only 20 kilometres from the Region's northern boundary, and the other in Moreton Bay near Brisbane, to the south of the Great Barrier Reef.

The potential for shipping activity to introduce non-native species into the Great Barrier Reef ecosystem is always present. Introduced species have been detected in ports along the Great Barrier Reef coast, both in port areas within the Great Barrier Reef Region and in nearby harbours. For example the Asian green mussel was detected in Cairns Port in 2001, 2002, 2007 and 2008, as well as in Gladstone Port in 2009 and the Asian bag mussel was detected in Cairns Port in 2007.[44] No introduced species have been detected in marine areas outside the ports.

The impacts of dredging and construction of port facilities - such as seabed disturbance, transport or resuspension of contaminants, alteration of sediment movement and changes in coastal processes - can be significant, but are localised. For example, monitoring of the Hay Point dredging project in 2007 showed significant environmental impacts at the dredge and disposal sites and minor impacts to corals at sites up to 12 kilometres away (recovery is expected at these sites).[45]

The movement of sediments in port areas means that corals and other marine life can be smothered by the fine particulate matter.

Although subject to careful environmental impact management, further development of ports within the Great Barrier Reef Region, such as an increase in construction of new shipping berths and shipping channels or an increase in maintenance dredging activities, are likely to have local impacts on the marine environment. While continued careful management of shipping activity will minimise the risk of major incidents, the predicted increase in shipping will increase the likelihood of a major incident as well as increasing the potential for more introduced species to occur.

4.6 Recreation (not including fishing)

4.6.1 Current state and trends of recreation

For the purposes of this Report, recreation is defined as an independent visit for enjoyment that is not part of a commercial operation. Both coastal residents and visitors to the area visit the Great Barrier Reef for recreation. Most recreational vessels are owned by people living in the major coastal urban centres such as Cairns, Townsville and Mackay (figure 4.19). The small size of private boats (figure 4.20) means that most are not suited to offshore trips. As a result, recreational use is mainly concentrated in inshore areas close to urban centres.

A survey of households conducted in 2008 estimated that 14.6 million recreational visits were made to the Great Barrier Reef Marine Park in the previous 12 months by residents living within the Great Barrier Reef catchment.[47]

About 60 per cent of recreational visitors visit the Great Barrier Reef between one and 10 times in a year, but a small proportion (about 15 per cent) visit the area more than 50 times a year (figure 4.21).

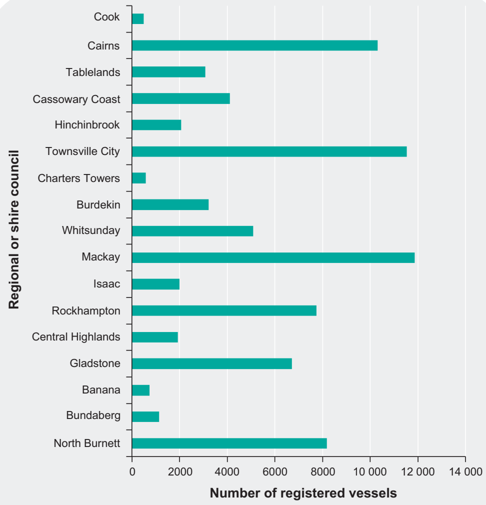


Figure 4.19 Recreational vessel distribution in the Great Barrier Reef catchment, 2007[46]

In the Great Barrier Reef catchment, most vessels are owned by people living in major urban centres. A total of about 80 000 vessels were registered in 2007.

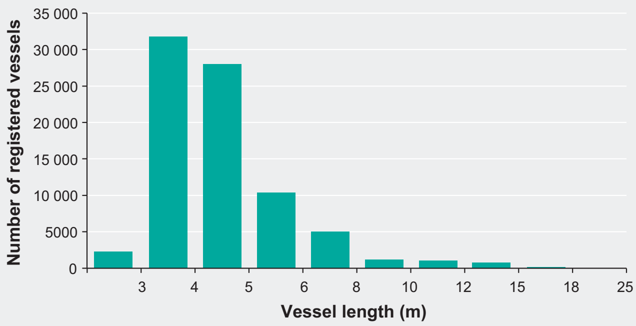


Figure 4.20 Registered recreational vessel size in the Great Barrier Reef catchment, 2007[46]

The size of a vessel limits the distances travelled during a visit to the Great Barrier Reef Region.

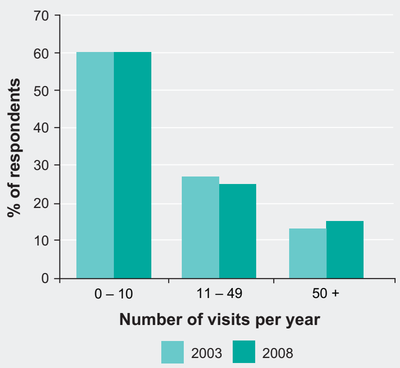


Figure 4.21 Frequency of visits to the Great Barrier Reef by recreational users[48]

Many people come infrequently to the Great Barrier Reef, while others are consistent users.

Swimming, boating, fishing and snorkelling are the most popular activities for people visiting the Great Barrier Reef (figure 4.22).

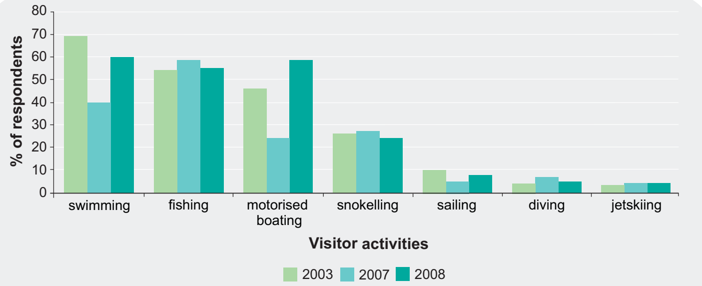
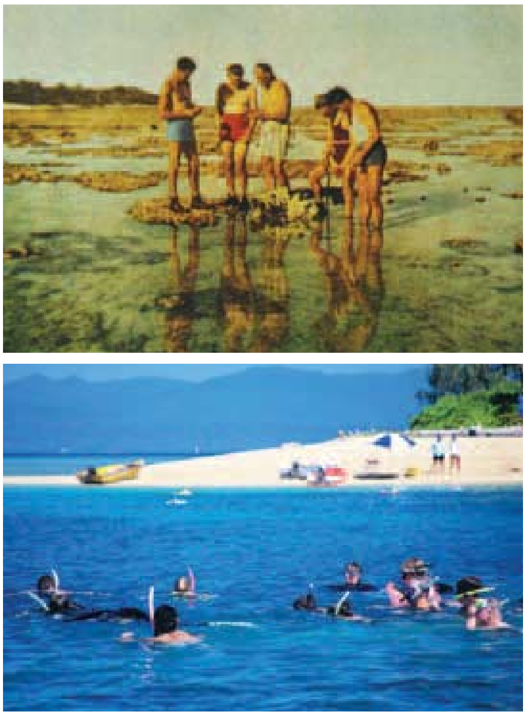


Figure 4.22 **Main activities of visitors to the Great Barrier Reef**[48 49]

People enjoy swimming, fishing, boating and snorkelling when they visit the Great Barrier Reef.

Visitors to the Great Barrier Reef are consistently very happy with their visit and would recommend the experience.

The types of activities undertaken by visitors on the Great Barrier Reef have remained relatively constant over the last few decades. What has changed are the technologies used to access and use the area, as well as the level of visitor awareness about the environment and their impacts on it. During the early and mid-twentieth century there was more emphasis on fishing and collecting (such as shells) and less on non-extractive recreation such as snorkelling and diving.[50]



The ways in which people experience the Great Barrier Reef have changed substantially over the decades[51]*, in both activity and number of participants. (Historical photo from 'Wonders of the Great Barrier Reef', Roughley, 1941)*

Management Recreational activities that do not involve fishing can be undertaken in almost all of the Great Barrier Reef Region. In the more intensively used areas (such as offshore Cairns and the Whitsundays), Plans of Management outline detailed measures for reducing the impacts of recreation, including specifying group and vessel size limits and no anchoring areas. Public moorings are provided throughout the Great Barrier Reef at some of the more popular recreational locations. Public education plays a major part in managing recreational use, along with compliance activities. Recreational vessel and personal watercraft registration and licensing are managed by Maritime Safety Queensland.

4.6.2 Benefits of recreation

Recreational use (including recreational fishing) contributed $153 million to the Australian economy in 2006/07 (table 4.1). The exact contribution of the non-fishing component is not known.

The level of satisfaction of recreational visitors to the Great Barrier Reef remained relatively constant between 2003 and 2007. Satisfaction has generally been high, with more than 80 per cent of all Australian and 70 per cent of Queensland visitors who were surveyed expressing satisfaction with their visit (figure 4.23). Bad weather and not being able to catch enough fish were the main factors contributing to visitor dissatisfaction. Most visitors were either not concerned about the number of other people or vessels around them or considered that the number was about right (figure 4.24).

Figure 4.23 **Satisfaction with a visit to the Great Barrier Reef**[48 52 53]

Visitors are consistently satisfied with their Great Barrier Reef experience.

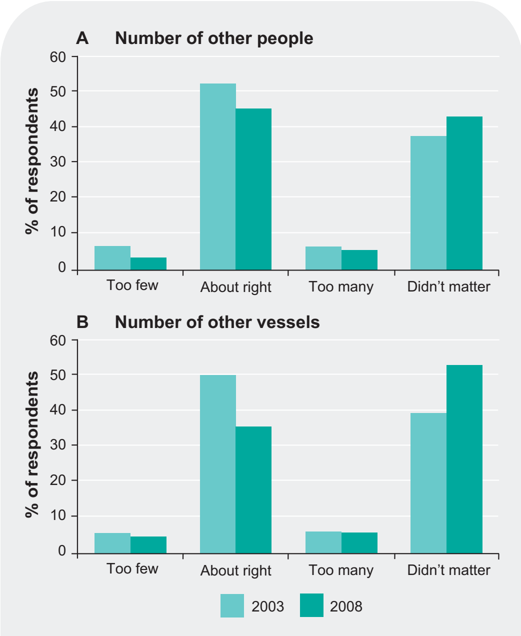


Figure 4.24 Effect of the number of other people and other vessels on satisfaction in the Great Barrier Reef[47 48]

Almost all people are satisfied with or unconcerned about the number of other people (A) or vessels (B) they see during their visit to the Great Barrier Reef.

4.6.3 Impacts of recreation

There have been few studies of the impacts of recreational use on the Great Barrier Reef ecosystem. Given the distribution of boat ownership and the size of vessels owned, any impacts are predicted to be principally in inshore areas close to major regional centres. Apart from fishing (Section 4.4.3), localised but frequent anchor damage to corals and seagrass meadows are likely impacts, along with littering, boat strikes on marine mammals and turtles, and fin damage to corals when snorkelling and diving. There is some risk of introducing species through fouling on recreational vessels, especially those from overseas.

The impacts of recreation (not including fishing) are mainly localised in inshore areas.

4.7 Scientific research

4.7.1 Current state and trends of scientific research

The Great Barrier Reef provides research opportunities for scientists from Australia and around the world and is an international hub of tropical marine ecosystem research. There is a long history of scientific investigation with the first formal investigations in the late nineteenth century. Now, the Great Barrier Reef is probably the best-studied tropical marine ecosystem in the world.

The Great Barrier Reef has long been important for tropical marine ecosystem research.

Scientists at work during the Yonge expedition, 1928
There is a long history of groundbreaking research in the Great Barrier Reef, including the year-long scientific expedition to Low Isles in 1928-29, led by Maurice Yonge. (Photo from Sir Maurice Yonge, Album #1)

Recollections of encounters with nature

Margaret Thorsborne lives nestled deep in a *Melaleuca* forest in the northern region of the Great Barrier Reef catchment. She has had an epic **career of activism and conservation** and recalls her visits to the Great Barrier Reef:

"Well there have been manta rays; it's lovely to see them over at Ramsay Bay. They just undulate… They're just the most beautiful, beautiful things. Well to see anything: to see dolphins; or to see a turtle just lift its head out of the water and breathe and go down again; to see a dugong do that and if you're lucky you see its mermaid tail as it goes under. You don't often see that, but that's pretty nice if you just see that beautiful mermaid tail."

Impacts of scientific research are concentrated primarily around research stations.

Management Scientific research is provided for in the *Great Barrier Reef Marine Park Zoning Plan 2003*. Scientific Research Zones provide opportunities for scientific research in relatively undisturbed areas. Individual research activities are managed through permits or accreditation of research institutions and strict conditions apply.

A network of island research stations is integral to the research activities (figure 4.25), and Scientific Research Zones are generally located adjacent to these research stations. The six island research stations are at Lizard Island, Low Isles, Green Island, Orpheus Island, Heron Island and One Tree Island.

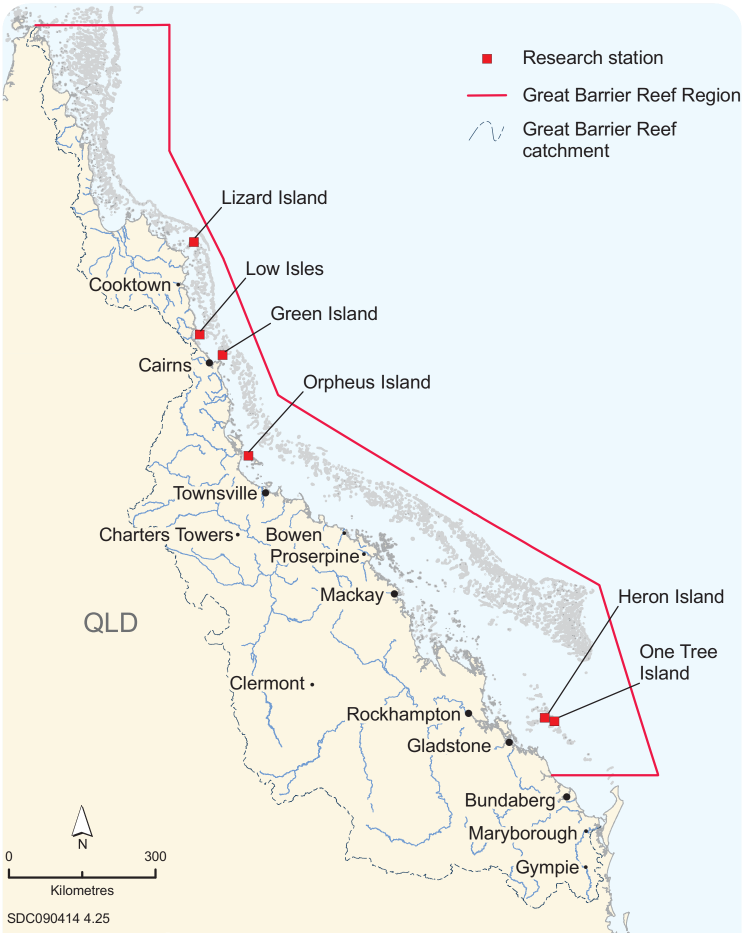


Figure 4.25 | **Scientific research stations of the Great Barrier Reef**

Scientific research stations are spread across the Great Barrier Reef and are the focus of research activities.

4.7.2 Benefits of scientific research

Research improves understanding of the Great Barrier Reef.

Scientific research is essential to understanding the functioning, health and resilience of the Great Barrier Reef ecosystem and to improving its protection and management. Examples of key scientific studies include:

- classifying 30 reef and 40 non-reef bioregions that provided a basis for the Representative Areas Program[54] (see figures 2.2 and 2.3)
- examining the effects of line fishing by experimentally opening and closing reefs to line fishing[55]
- long-term monitoring of coral and fish[56]
- seagrass surveys[57]
- marine turtle population[58] and dugong population estimates[59 60]
- examining the effects of trawling and the associated recovery of benthic habitats[36]
- extensive studies of Great Barrier Reef water quality[61]
- a better understanding of the seafloor through the Seabed Biodiversity Project.[62]

Most research has focused on the biophysical environment. Today, social and economic research is recognised as an increasing need as the intensity and economic values of human uses increase.

The findings of scientific research are often the foundation of information about the Great Barrier Reef ecosystem and its use, and are provided to both stakeholders and the wider community.

Scientific research on the Great Barrier Reef also contributes to training and capacity building for researchers throughout Australia and internationally.

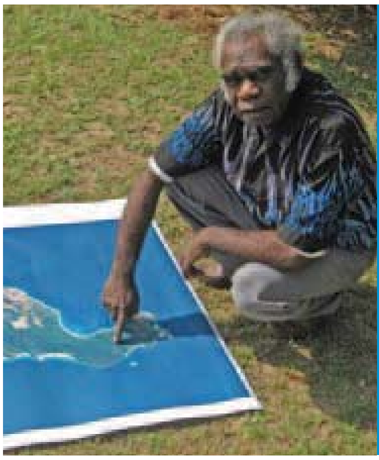
4.7.3 Impacts of scientific research

Much of the research activity on the Great Barrier Reef is confined to areas surrounding the six island research stations, with approximately 80 per cent of scientific research being concentrated around Lizard, Heron and Orpheus Islands. With ongoing management, any impacts of research are likely to be small and localised to the immediate area of study.

4.8 Traditional use of marine resources

4.8.1 Current state and trends of traditional use

Aboriginals and Torres Strait Islanders have lived along the east coast of Queensland for over 40 000 years. The Great Barrier Reef is 'sea country' for Traditional Owners — part of their culture, spirituality and



Traditional Owner sea country creation story

Walter Palm Island, Manbarra Traditional Owner, Palm Island region tells of the Dreamtime in his sea country:

"In the Dreamtime, the rainbow serpent Gubal, moved through the Palm Island group and surrounding areas, leaving a track as he went. When the sea levels rose, a giant stingray came and found a place to stay. This makes the boundaries between Manbarra, Nywaigi and Wulgurukaba."

livelihoods. Today, there are about 70 Traditional Owner groups with connections to the Great Barrier Reef. Traditional Owners continue to visit and maintain connections with their traditional sea country, including traditional hunting and fishing, ceremonies, stories and looking after their country. This is known as traditional use of marine resources - the undertaking of activities as part of Traditional Owner custom and tradition to satisfy personal, domestic or communal needs.[63]

The Great Barrier Reef includes many places of cultural significance to Traditional Owners. Most common are sacred sites, story places and fish traps. On many of the islands and in areas directly adjoining the Great Barrier Reef there are shell middens and mounds, rock shelters, stone quarries, rock art sites, hearth and oven sites and stone artefact scatters.

For Traditional Owners with sea country, totems (an object or thing in nature such as birds, reptiles and fish that is adopted as a family or clan emblem) are often Great Barrier Reef species. In some cases they are species of conservation concern such as dugongs and marine turtles.[64]

Notwithstanding the high level of relocation of Traditional Owners since European settlement, for many groups social and cultural structures remain, allowing the continuation of the oral cultural tradition, with stories handed down for thousands of years. Generally, stories belong to a specific Traditional Owner group and convey how ancestral spirits created all things on Earth; why things happen; where to go or where not to go; how to find food; cultural practices, laws, history, family associations; tribal boundaries and relationships with country.[65]

Climate change is not a new concept for Indigenous communities, and many Traditional Owner groups have stories about previous changes in climate. Gungandji Traditional Owners of the Cairns region tell stories of the Great Barrier Reef as a recent development and talk about cultural heritage sites from before the last ice age that are now below the sea surface, such as burial sites and fish traps.

A number of Traditional Owner groups are pursuing Native Title claims over various areas of the Great Barrier Reef Region. To the end of 2008, no decisions had been made on these applications.

Management Provision for traditional use of marine resources is made under the Zoning Plan, allowing use in all zones (including non-extractive use in Preservation Zones). Traditional Owners have the opportunity to formalise their aspirations for sea country management through agreements involving government agency partners. These include Traditional Use of Marine Resources Agreements (TUMRAs), Indigenous Land Use Agreements (ILUAs) and Memoranda of Understanding (MOUs). In the Great Barrier Reef Region, there are four TUMRAs in place (covering more than 19 000km^2) (figure 4.26), two MOUs and two ILUAs. In addition, some Traditional Owner groups have agreed arrangements within their communities regarding sea country management, but have chosen not to formalise these arrangements with government agencies.

For most of the time since late 1996, a Traditional Owner from the Great Barrier Reef Region has been a member of the Great Barrier Reef Marine Park Authority Board contributing to the setting of policy and management direction for the Great Barrier Reef Marine Park. There is also the opportunity for Indigenous representation on each of the four Reef Advisory Committees and the 11 Local Marine Advisory Committees.

Each Traditional Owner group has totems, stories and ceremonies connected to the Great Barrier Reef.

There is a range of opportunities for Traditional Owners to formalise their aspirations for sea country management.

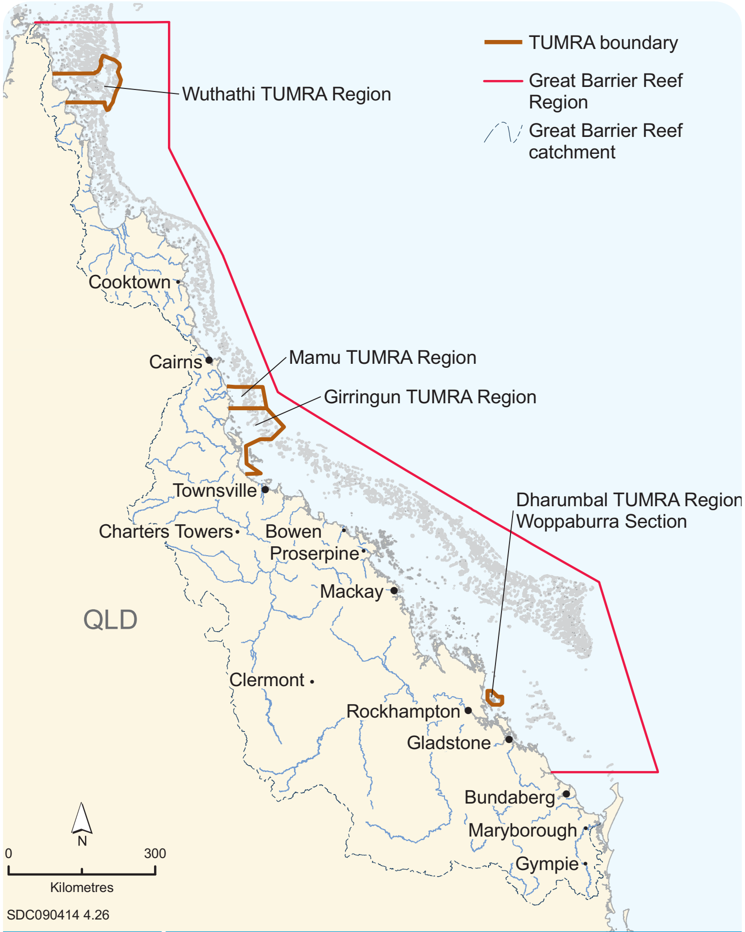


Figure 4.26 **Areas of the Great Barrier Reef covered by Traditional Use of Marine Resource Agreements with Traditional Owner groups**

Some Traditional Owners have formalised their aspirations for sea country through Traditional Use of Marine Resource Agreements with government agency partners.

4.8.2 Benefits of traditional use

Traditional use of marine resources provides environmental, social, economic and cultural benefits to Traditional Owners and their sea country.

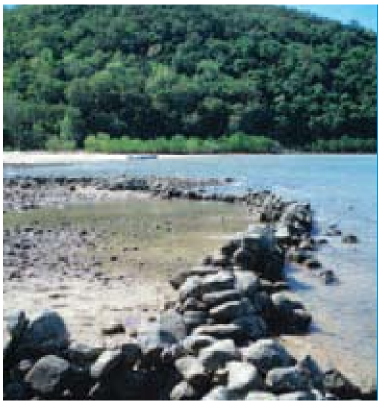
Traditional Owners' inherent ethos to care for their sea country results in environmental benefits to the Great Barrier Reef ecosystem. Over the last 15 years many Traditional Owner groups on the Great Barrier Reef have initiated marine resource management projects. Examples include preparation of a Sea Plan by members of the Lockhart River Aboriginal Community in 1995 (including a commitment to monitor and sustainably use dugongs and marine turtles); collaboration in research about dugongs and marine turtles; voluntary agreements to suspend dugong hunting; Indigenous ranger programs and negotiated Traditional Use of Marine Resources Agreements.[66]

Direct Traditional Owner involvement in natural resource management activities not only brings environmental benefits to an area but also economic participation, development opportunities and health and social benefits to the broader Indigenous community[67] by restoring relationships and reinforcing family and community structures.[68] This reinforces Traditional Owner culture, protocols and connections to the Great Barrier Reef. Traditional Owner communities also derive benefit from the reinforcement of social networks through the customary sharing of food and the passing of traditional and customary harvesting practices to a younger generation.[69]

A Hopevale elder passing on traditional knowledge of country.

Hunting is one way in which Traditional Owner groups maintain connections with culturally significant species and it is recognised under the Australian Government's *Native Title Act 1993*. Traditional hunting of dugongs and marine turtles requires skills and knowledge, and is traditionally governed by strict protocols relating to who can hunt, where and how they hunt, and how the animal is killed, butchered and shared.[64]

Green turtles are culturally significant to Great Barrier Reef Traditional Owners.



Traditional Owner responsibilities

Darren Butler, **Bandjin Traditional Owner**, Hinchinbrook Island region explains his responsibilities to his traditional culture:

> *"I've got to make sure that after our Elders are gone, we keep our cultural heritage intact, we look after the cultural heritage sites like fish traps and story places that are very important to us as a group."*

4.8.3 Impacts of traditional use

Traditional use, mainly through hunting, fishing and collecting, involves a range of marine species but overall levels of take are thought to be low. Some species of conservation concern, such as marine turtles and dugongs are targeted, although the numbers taken are unknown. Many Traditional Owners have recognised the decline in dugong populations along the urban coast (Section 2.3.8) and have voluntarily decided to not hunt dugongs until such time as the population can sustain a harvest. The traditional hunting of threatened species such as dugongs and green turtles must be balanced with other factors that cause mortality to these species, such as disease, incidental catch in fishing gear and boat strike.

In addition to the traditional use of marine resources, illegal hunting of threatened species by people who are not Traditional Owners (also known as poaching) is known to occur and is of concern to both Traditional Owners and managing agencies. This is more prevalent in some areas.

Traditional use, mainly hunting, fishing and collecting, involves a range of marine species (some of conservation concern) but levels of take are thought to be low.

The Girringun, Woppaburra, Mamu and Wuthathi Traditional Owner groups have signed Traditional Use of Marine Resources Agreements with the Australian and Queensland Governments.

4.9 Assessment summary - Commercial and non-commercial use

Section 54(3)(c) of *the Great Barrier Reef Marine Park Act 1975* requires '*… an assessment of the commercial and non-commercial use …*' of the Great Barrier Reef Region. The assessment is based on two assessment criteria:

- benefits of use
- impacts of use.

4.9.1 Benefits of use

Assessment component	Summary	Assessment Grade: Very good	Good	Poor	Very poor
Commercial marine tourism	Tourism makes a significant contribution to the presentation, management and economic value of the Great Barrier Reef.	●			
Defence	Activities in the Great Barrier Reef directly contribute to the training and operations of Australia's defence services.		●		
Fishing	Fishing provides opportunities for recreation, resources for the seafood industry, and generates regional economic value.		●		
Ports and shipping	Adjacent ports and shipping through the Great Barrier Reef service central and northern Queensland industries and communities.	●			
Recreation (not including fishing)	Visitors to the Great Barrier Reef are consistently very happy with their visit and would recommend the experience.	●			
Scientific research	Research improves understanding of the Great Barrier Reef and allows management to be based upon the best available information.	●			
Traditional use of marine resources	Traditional use of marine resources provides environmental, social, economic and cultural benefits to Traditional Owners and their sea country.	●			
Benefits of use	Use of the Great Barrier Reef contributes strongly to the regional and national economy and local communities. Its economic value is derived almost exclusively from its natural resources, either through extraction of those resources or through tourism and recreation focused on the natural environment, and would be affected by declines in those resources. Millions of people visit the Great Barrier Reef every year and are very satisfied with their visit. The Great Barrier Reef is valued well beyond its local communities, with strong national and international scientific interest. The Great Barrier Reef is of major importance to Traditional Owner culture. Some users financially contribute to management.	◉			

GRADING STATEMENTS

Very good - Use of the Region makes a significant contribution to the environmental, economic and social values of the Region, in ways that sustain the fundamental value of the natural resource. The Region is strongly recognised, valued and enjoyed by catchment residents, the nation and the world community.

Good - Use of the Region makes a valuable contribution to the environmental, economic and social values of the Region. The Region is valued by catchment residents, the nation and the world community.

Poor - There is a small and strongly declining contribution to the environmental, economic and social values of the Region. Many do not recognise the value of the Region and do not enjoy their visit to the Region.

Very poor - Use of the Region contributes little or nothing to the environmental, economic and social values of the Region. The Region holds little value for catchment residents, the nation or the world community.

4.9.2 Impacts of use

Assessment component	Summary	Assessment Grade: Very low impact	Low impact	High impact	Very high impact
Commercial marine tourism	Marine tourism extends throughout the Great Barrier Reef but its impacts are concentrated in a few intensively managed areas.	●			
Defence	The majority of routine defence training activities have negligible impacts.	●			
Fishing	There is limited information about many targeted species and of the survival success of discarded species resulting in a poor understanding of the ecosystem effects of fishing.			?	
Ports and shipping	Most routine shipping activities have negligible consequences. Dredging and construction of port facilities can have significant but localised impacts.		●		
Recreation (not including fishing)	The impacts of recreation (not including fishing) are mainly localised in inshore areas.		●		

Assessment component	Summary	Assessment Grade: Very low impact	Low impact	High impact	Very high impact
Scientific research	Impacts of scientific research are concentrated primarily around research stations.	●			
Traditional use of marine resources	Traditional use, mainly hunting, fishing and collecting, involves a range of marine species (some of conservation concern) but levels of take are unknown. Poaching by non-Traditional Owners is a concern for Traditional Owners and management agencies.			?	
Impacts of use	The impacts of different uses of the Great Barrier Reef overlap and are concentrated inshore and next to developed areas. There are some concerns about localised impacts and effects on some species. In particular, species of conservation concern such as dugongs, some bony fish, sharks, seabirds and marine turtles are at risk, especially as a result of fishing, disturbance from increasing use of coastal habitats, illegal fishing, poaching and traditional use of marine resources. There is evidence that fishing is also significantly affecting the populations of some targeted species. The survival success of non-retained species is not well understood, nor are the ecosystem effects of fishing.		◎		

GRADING STATEMENTS

Very low impact - Any impacts attributable to use of the Region are minor and localised, with no observable effects on overall ecosystem function.

Low impact - The impacts of use are observable in some locations or to some species, but only to the extent that limited additional intervention would be required for the ecosystem to be used sustainably. Enjoyment of some aspects or some areas is reduced.

High impact - The impacts of use are obvious in many locations or for many species to the extent that significant additional intervention would be required for the ecosystem to be used sustainably. Enjoyment is substantially reduced.

Very high impact - The impacts of use are widespread, to the extent that ecosystem function is severely compromised. Opportunities to enjoy the Region are limited.

4.9.3 Overall summary of commercial and non-commercial use

Almost all commercial and non-commercial uses of the Great Barrier Reef Region are dependent on the biodiversity and health of its ecosystem. Use occurs across the length and breadth of the ecosystem with most use and impact concentrated inshore, near developed coasts and on coral reef habitats. The current state and trends of most uses are known, with fluctuations largely determined by global factors such as fuel prices, human health issues and economic development. There are some concerns about localised impacts and effects on some species with potential flow on effects to some ecological processes.

Uses of the Great Barrier Reef are economically important to regional communities and tourism is economically important nationally. They provide income to and employment for local industries and are an integral component of coastal communities. Traditional Owner aspirations are being increasingly recognised and formalised in law. However, they are also being increasingly impacted by other activities occurring in the Great Barrier Reef and along the adjacent coastal zone.

Declines in many coral reef ecosystems around the world are likely to increase the commercial and non-commercial value placed on components of the Great Barrier Reef and potentially alter use patterns in the future. Overall trends of use of the Great Barrier Reef are difficult to predict because each use is shifting at different rates and in response to different drivers. The future cumulative effects of all use and the ecosystem-level impacts are poorly understood.

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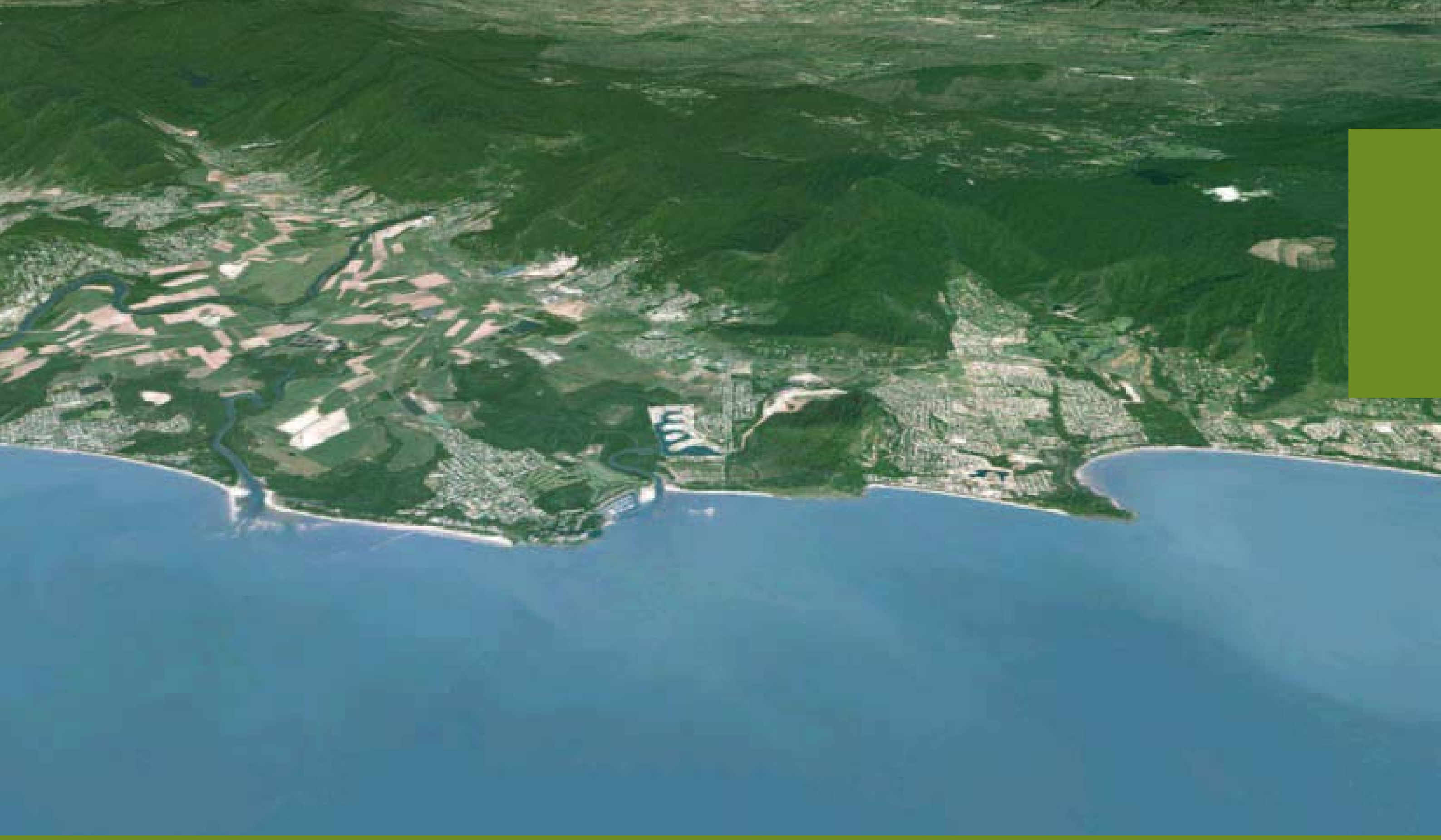


FACTORS INFLUENCING THE REEF'S VALUES

CHAPTER FIVE

"With more intensive use of the coastal watershed and growing awareness of the cumulative impact on the reef of land-based activities, pressure to manage the region as an integrated ecosystem has already begun to grow. It will continue. Indeed, it does not require great insight to see that land use and water quality will become the central issues in the management of the Great Barrier Reef in the years ahead."

Gary L. Sturgess, 1999
The Great Barrier Reef partnership: a report into the review of the relationships of the Commonwealth and Queensland Governments in respect of the Great Barrier Reef

'an assessment of the factors influencing the current and projected future environmental, economic and social values…' of the Great Barrier Reef Region, Section 54(3)(g) of the *Great Barrier Reef Marine Park Act 1975.*

5 FACTORS INFLUENCING THE REEF'S VALUES

5.1 Background

The experience of the last two decades has shown that much of what will happen to the Great Barrier Reef in the future will be determined by factors external to it and to Australia (figure 5.1). Although the Great Barrier Reef is a vast and complex ecosystem, it is but a small part of the Earth's biosphere and, ultimately, depends on the overall state of the region and the Earth for its continuing health.

This assessment of the factors that currently and are projected to influence the Great Barrier Reef's environmental, economic and social values addresses the three major external factors – climate change, coastal development and catchment runoff. It also considers the influence of direct use of the Region, based on the information outlined in Chapter 4. All these factors are significant to the ecosystem's functioning and resilience.

5.2 Climate change

The Earth's climate has always been changing. The cycles of ice ages ending, glaciers melting and sea level rising is a natural phenomenon. The difference today is that the change is happening faster than anything experienced for many millions of years.

The changing world climate is being accelerated by human activities (especially the combustion of fossil fuels). Gases in the Earth's atmosphere trap some of the sun's energy that would otherwise be radiated back into space. This is called the greenhouse effect and keeps the Earth at a temperature suitable for life. Climate change results from an enhanced greenhouse effect. Increased levels of greenhouse gases (mostly carbon dioxide) in the atmosphere mean that more heat is being trapped and the Earth's temperature is increasing. There is now consensus that emissions from human activities are largely responsible for enhanced concentrations of greenhouse gases.[1]

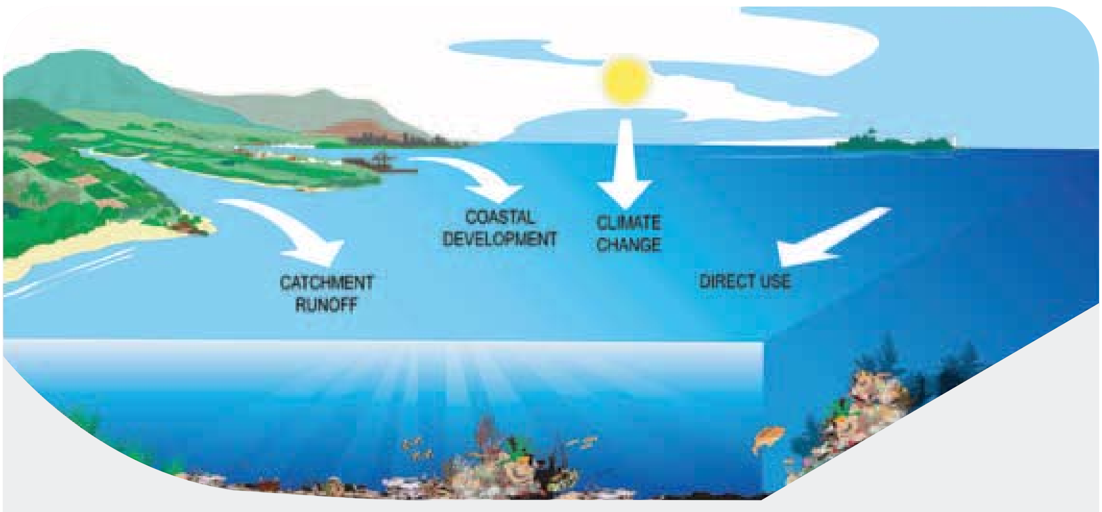


Figure 5.1 Major factors that are influencing the Great Barrier Reef

Global climate change, coastal development and catchment runoff are the key external factors influencing the environmental, economic and social values of the Great Barrier Reef. From within the Region itself, direct use can also have an influence.

Atmospheric carbon dioxide, the principal gas of concern, is at concentrations that are unprecedented within the last 400 000 years (figure 5.2). The rapid increase in emissions of carbon dioxide and other greenhouse gases since the Industrial Revolution has amplified their natural role in retaining the Earth's heat. The pre-industrial concentration of atmospheric carbon dioxide was about 277 parts per million (ppm). Today's concentration is 387ppm, an increase of almost 40 per cent.

5.2.1 Current state and trends of climate change

Global projections On a global scale, updated data[3 4] since the latest Inter-governmental Panel on Climate Change report[1] show that global temperature increase is tracking at or above the Panel's worst-case scenario and that the rate of sea level rise is near the upper limit of its wide range of forecasts. For a range of atmospheric carbon dioxide concentrations, global projections include:

- **400ppm** Average global temperature is projected to be 1°C higher than pre-industrial levels. Melting of ice in the Arctic Circle will create a sea level greater than 11cm higher than it is today. The effects of ocean acidification will begin to be apparent.
- **450ppm** Average global temperature is likely to have increased by 1.5°C (range=0.8–2.1°C). These levels are often considered to be the threshold for "dangerous climate change" at which point diverse and largely irreversible impacts occur. Sea level is expected to be at least 20cm higher than today. Ocean acidification will further affect the growth of most species that build shells or skeletons.
- **500ppm** Average global temperature is expected to have increased by nearly 3°C. Sea level will be determined by largely unpredicted rates of melting of the Greenland and West Antarctic ice shelves and thermal expansion. Ocean acidification is likely to be severely affecting the growth of corals. Cyclones are predicted to have significantly increased in severity.[3]
- **550ppm** Oceans are likely to be highly acidic (e.g. -0.25 pH units lower), sea temperatures are expected to be an average of 3°C higher, storm intensity is likely to have increased even further.
- **No mitigation** In the absence of mitigation; temperatures would likely rise by 5.1°C (range = 3-6.6°C); sea level would rise by 26-59cm; ocean pH would decrease to between 4.7 and 6.8.

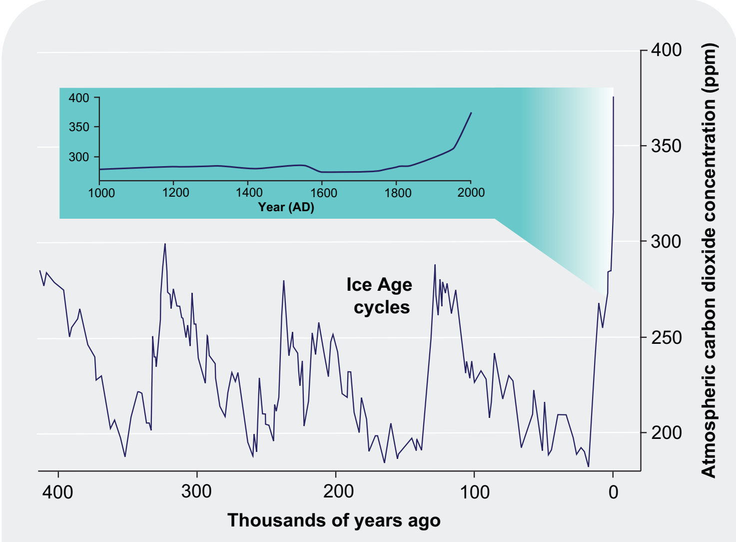


Figure 5.2 Carbon dioxide concentrations in the atmosphere over the past 400 000 years

Concentrations of carbon dioxide in the Earth's atmosphere have fluctuated over the past 400 000 years. The Industrial Revolution has caused a dramatic rise in these concentrations. (Adapted from Global Warming Art[2])

Concentrations of greenhouse gases continue to increase around the world.

Great Barrier Reef projections A number of climate change variables are already changing, and based on a combination of global climate projections and regional observations and models, are projected to change substantially in the Great Barrier Reef Region over the next 50 years[5] (table 5.1).

Specific climate projections have not been published for the Great Barrier Reef. The current and projected future trends, their impacts on the ecosystem (see Section 5.2.2) and on regional communities (see Section 5.2.3) are detailed below. These variables do not work in isolation to one another. For example, as more carbon dioxide is released into the atmosphere, the sea temperature is likely to rise, melting glaciers at the Earth's poles and, in turn, causing the sea level to rise.

Table 5.1 Summary of projections for the Great Barrier Reef as a result of climate change

The projections are based on the Intergovernmental Panel on Climate Change (IPCC) scenarios. B1 - lower emissions with a global population peak in mid-century, rapid changes in economic structures, and the introduction of clean and resource-efficient technologies; A2 - high emissions with continuously increasing global population and economic growth and fragmented and slow technological change. Sea level increase is measured relative to a 1961 to 1990 baseline. (Adapted from Lough, 2007[5])

Variable	Regional variation and certainty	Current	Projections			
			IPCC B1 scenario		IPCC A2 scenario	
			2020	2050	2020	2050
Atmospheric carbon dioxide	High certainty, already observed increases; may accelerate.	384ppm (global)	421ppm	479ppm	440ppm	559ppm
Air temperature	Greater increase inland than along coast. High certainty, already observed increases.	23.2°C (Qld)	+0.6°C	+0.9°C	+1.4°C	+2.6°C
Sea surface temperature	Greater increase in southern Great Barrier Reef and in winter. High certainty, already observed increases.	25.9°C (Great Barrier Reef)	+0.5°C	+1.1°C	+0.5°C	+1.2°C
Sea level	Up to 0.9m by 2100. High certainty, already observed; may accelerate.	2.9mm/year since 1991 (near Townsville)	+7cm	+13cm	+38cm	+68cm
Ocean acidification	Decrease in pH of 0.5 units by 2100. High certainty, already observed decreases.	8.2 (global)	-0.06	-0.15	-0.10	-0.25
Weather variability	Similar spatial and inter-annual variability. High certainty for increased intensity.		No consensus. El Niño Southern Oscillation likely to be a continued source of aperiodic disturbance in the Region. Intensity of drought associated with given rainfall deficit will be increased due to higher temperatures. Intensity of high rainfall events will increase with more extremes. Intensity of tropical cyclones expected to increase.			


Coral bleaching

All over the tropics, most corals live in partnership (symbiosis) with single-celled algae (zooxanthellae). Corals provide protection and nutrients for the algae, and the algae produce food for the coral and give it its colour. When corals are under stress, for example when they become too hot, they expel their zooxanthellae, thus losing their colour and appearing bleached. Corals can survive for days or weeks without the algae, but if they are stressed for too long or too severely and do not regain algae, they will die. Some corals have different susceptibility to elevated sea temperatures. The shape of the coral has an influence on its potential for bleaching, with plate and branched corals more susceptible.[6]

Increased seawater temperature The average annual sea surface temperature on the Great Barrier Reef is likely to continue to rise over the coming century and could be as much as 1 to 3°C warmer than the present average temperature by 2100. Whatever climate scenario is used, it is predicted that, by 2035, the average sea surface temperature will be warmer than any previously recorded (figure 5.3). It is likely that sea surface temperature might warm more in winter and in the southern Great Barrier Reef. Projected increases in average sea surface temperature indicate that by 2020 it could be 0.5°C warmer and greater than 1°C warmer by 2050.[5]

Increasing sea temperature is a significant risk factor for the Great Barrier Reef over the short to medium term (decades) because of its effect on coral reef habitats, with flow-on effects throughout the entire ecosystem.[5] For most organisms, increases in temperature reduce their metabolic activity causing stress and making the animal more susceptible to disease and predation.

There have been a number of bleaching events in the Great Barrier Reef[7 8], the most severe mass bleaching events spanned the summer seasons of 1997/98 and 2001/02[9 10 11] resulting from prolonged elevated sea temperatures. During both events over 50 per cent of reefs were affected by bleaching, with lasting damage to an estimated five per cent of reefs (figure 5.4). The 1997/98 mass bleaching coincided with the highest sea surface temperatures ever recorded on the Great Barrier Reef[10] and was also when 500-year-old corals died, strong evidence that mass bleaching is a recent phenomenon.

Another bleaching event occurred in 2006 in the southern Great Barrier Reef in the Keppel Bay region. During this event 40 per cent of corals died but the reefs have subsequently shown strong recovery[12] (see figure 7.4).

A future predicted increase of 2°C in the average sea temperature will likely lead to annual bleaching, with up to 97 per cent of reefs affected and almost certain regular large scale mortality.[11]

Increased sea level Sea level on the Great Barrier Reef has already risen by approximately 3mm per year since 1991 (see Section 3.2.5), due to a combination of thermal expansion in the

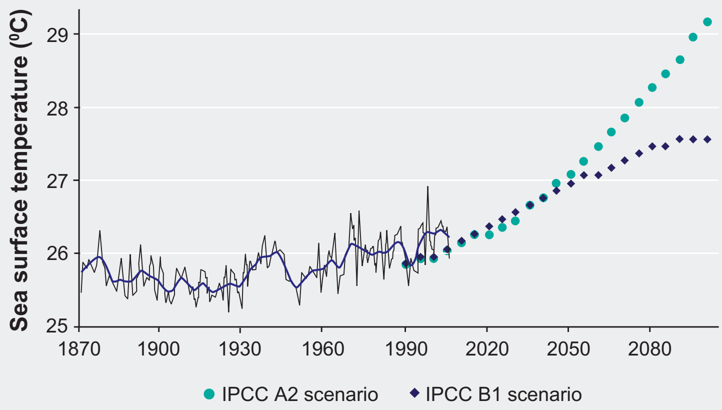


Figure 5.3 Observed and predicted sea surface temperature on the Great Barrier Reef[5]

Average sea temperature fluctuates from year to year, but is increasing overall. It is predicted to keep increasing in the range shown by the dotted lines depending on the extent of carbon dioxide emission reduction. Scenarios are those developed by the Intergovernmental Panel on Climate Change.

oceans and ice melting. Responses of sea level to temperature increases are time-dependant and uncertain, because they are in part a response to the collapse of the Earth's great ice shelves. Predictions of future increase are highly variable and range from 0.68m across the Great Barrier Reef Region to a global increase of up to 0.9m by 2100.[5]

Coral reef and coastal habitats are particularly vulnerable to increasing sea temperature.

These rises in sea level are significant ecologically as many habitats are shallow and strongly influenced by sea level. In particular, because much of the Great Barrier Reef coastline is low lying, small changes in sea level will mean land inundation, causing significant changes in tidal habitats such as mangroves and saltwater intrusion into low lying freshwater habitats.

Sea level is rising in the Great Barrier Reef.

Increased weather variability There are no observable trends in the frequency or severity of El Niño Southern Oscillation (ENSO) events (El Niño, La Niña) although the strongest El Niño event ever recorded was as recent as 1997/98.[5] The relationship between ENSO and climate change remains largely unknown. Given the importance of ENSO to inter-annual climate variability along the Great Barrier Reef, the uncertainty of the effects of climate change mean that future changes to rainfall, river flow and tropical cyclones are difficult to predict.

Weather events are likely to become more extreme and severe.

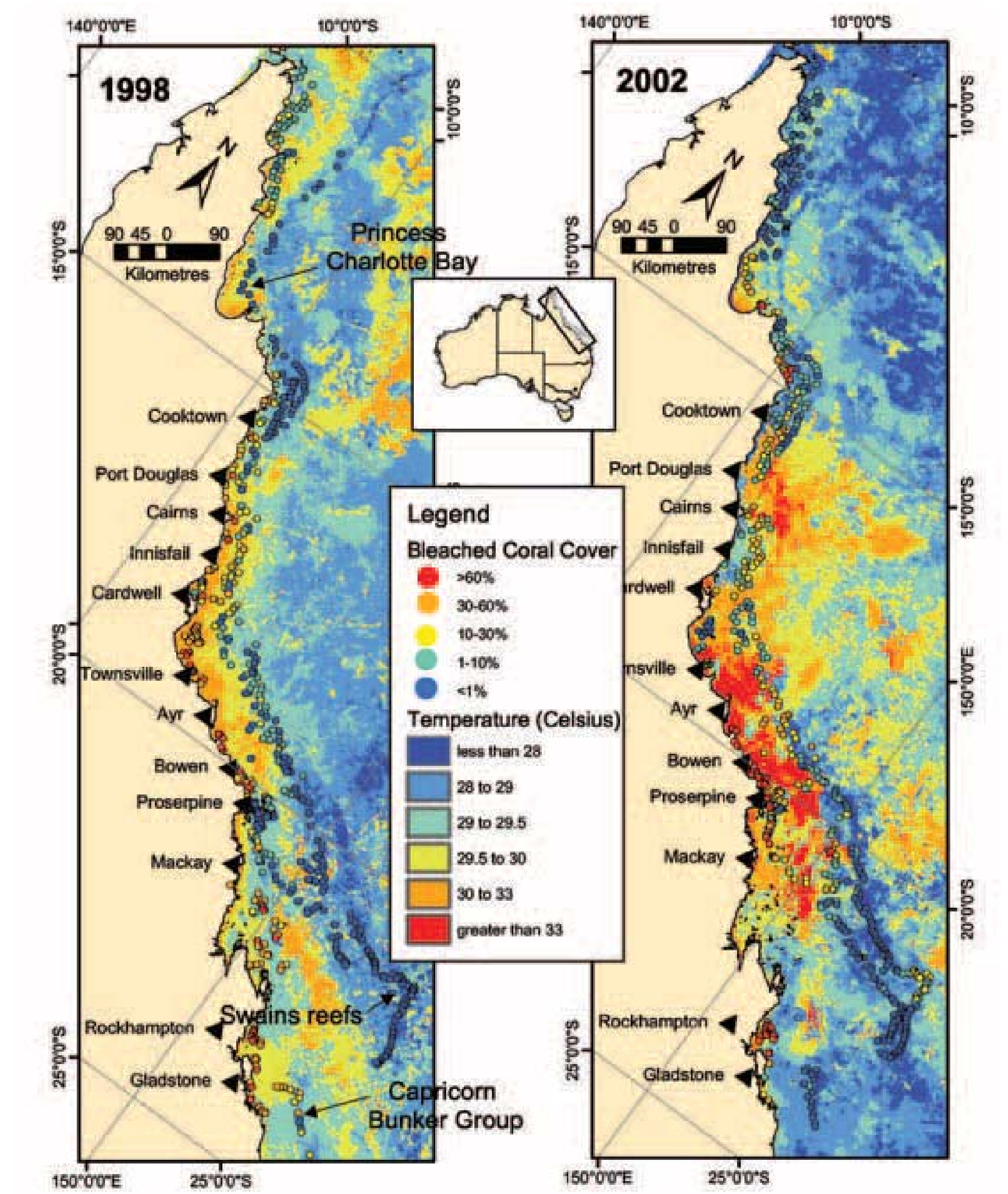


Figure 5.4 Coral bleaching on the Great Barrier Reef, 1997/98 and 2001/02[11]

Results of aerial surveys of coral bleaching in 1997/98 and 2001/02 overlaid on the maximum three-day sea surface temperature during the warmest austral summer months (December– March).

Nevertheless, current observed patterns of tropical cyclones around the world indicate an increase in severity (and therefore, destructive potential). Within Australia, although the number of cyclones was lower during the period 1970 to 1997, there was an increase in the severity of those that did form.[13] In 2009, one of the most severe cyclones ever recorded damaged the southern part of the Great Barrier Reef (Section 3.2.2) and there have been three category five cyclones in the past five years. Projections indicate an increase in the intensity, but not frequency, of cyclones.[5]

Rainfall is highly variable both within and between years along the Great Barrier Reef. Whilst there is no consensus amongst scientists in regard to projections of changes in average rainfall, it is likely that there will be increased intensity in both high rainfall events and droughts.[5] A decline in annual rainfall and higher evaporation would likely reduce runoff to rivers, including the Fitzroy and Burdekin Rivers.[14]

Ocean acidification In the long-term, ocean acidification is likely to be the most significant climate factor affecting the Great Barrier Reef ecosystem. When carbon dioxide dissolves in seawater (about half of all global carbon dioxide production) some of it is taken up by phytoplankton during photosynthesis. This carbon either enters food chains or is removed from surface water when the plankton dies and sinks. The remaining carbon dioxide forms carbonic acid which reacts with carbonate and bicarbonate ions (the ocean's natural buffers) in the ocean causing the former to change to the latter. This is a natural process which removes carbon dioxide from both the atmosphere and the oceans (figure 5.5).

As the concentration of atmospheric carbon dioxide increases, it overwhelms the capacity of phytoplankton to take it up. It also decreases the carbonate ion content of the ocean surface waters causing a decrease in pH. Chemical changes in the ocean have already decreased oceanic pH by 0.1 units (Section 3.3.3). From a current pH of 8.2 (alkaline), it is predicted that the ocean's pH could fall to about 7.8 (still slightly alkaline) by 2100.[5] The predicted rate of change is estimated to be 100 times faster than over the past million years.[5]

Acidification will ultimately affect all the oceans of the world but will affect equatorial regions last because carbon dioxide is relatively insoluble in warm water (figure 5.6). Impacts are already being observed on the Great Barrier Reef (Section 3.3.3).

Great Barrier Reef waters are predicted to become more acidic.

Although the chemistry of ocean acidification is simple and well understood, its effect on marine life is much less well-known as the process has only been recognised for less than a decade. Even relatively small increases in ocean acidity decrease the capacity of corals to build skeletons (Section 3.3.3), which in turn decreases their capacity to create habitat for reef biodiversity in general.[17] It also decreases the capacity of coralline algae to cement reef debris together into solid limestone as well as affecting molluscs, phytoplankton and foraminifera. Increased ocean acidification may also affect the olfactory discrimination and homing ability of marine fish.[18]

5.2.2 Vulnerability of the ecosystem to climate change

Understanding the vulnerability to the effects of climate change on habitats, and the species that depend on them, and how long these changes may take, is critical to predicting the outlook for the Great Barrier Reef. Vulnerability is a measure of exposure and sensitivity to a potential impact as well as capacity to adapt to the impact.

Almost all Great Barrier Reef species will be affected by climate change, some seriously.

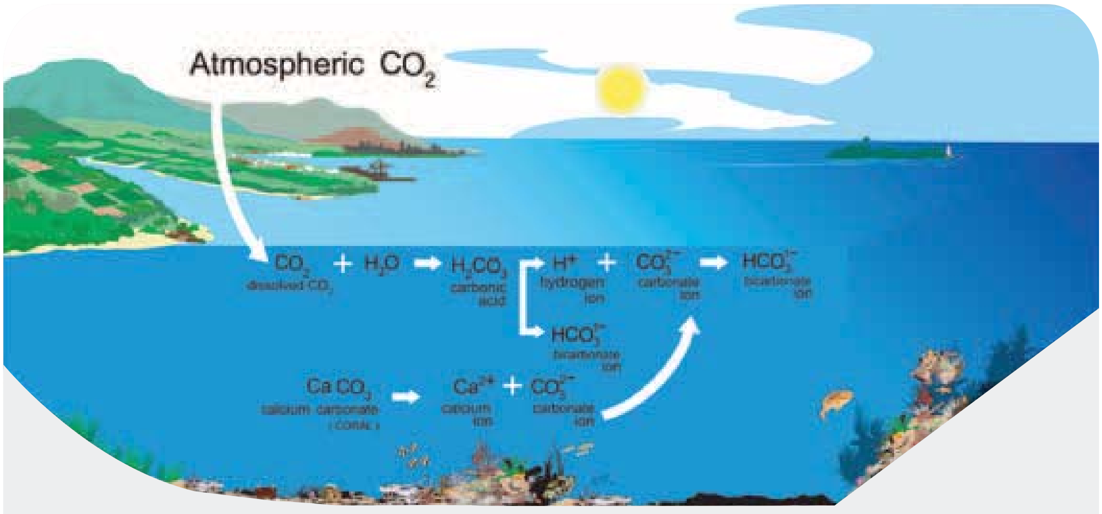


Figure 5.5 **The process of ocean acidification**[15]

As carbon dioxide (CO_2) is absorbed from the atmosphere it bonds with sea water forming carbonic acid. This acid then releases a bicarbonate ion and a hydrogen ion. The hydrogen ion bonds with free carbonate ions in the water forming another bicarbonate ion. The free carbonate would otherwise be available to marine animals for making calcium carbonate shells and skeletons. Hence the more dissolved carbon dioxide in the ocean, the less carbonate ions available for making calcium carbonate.

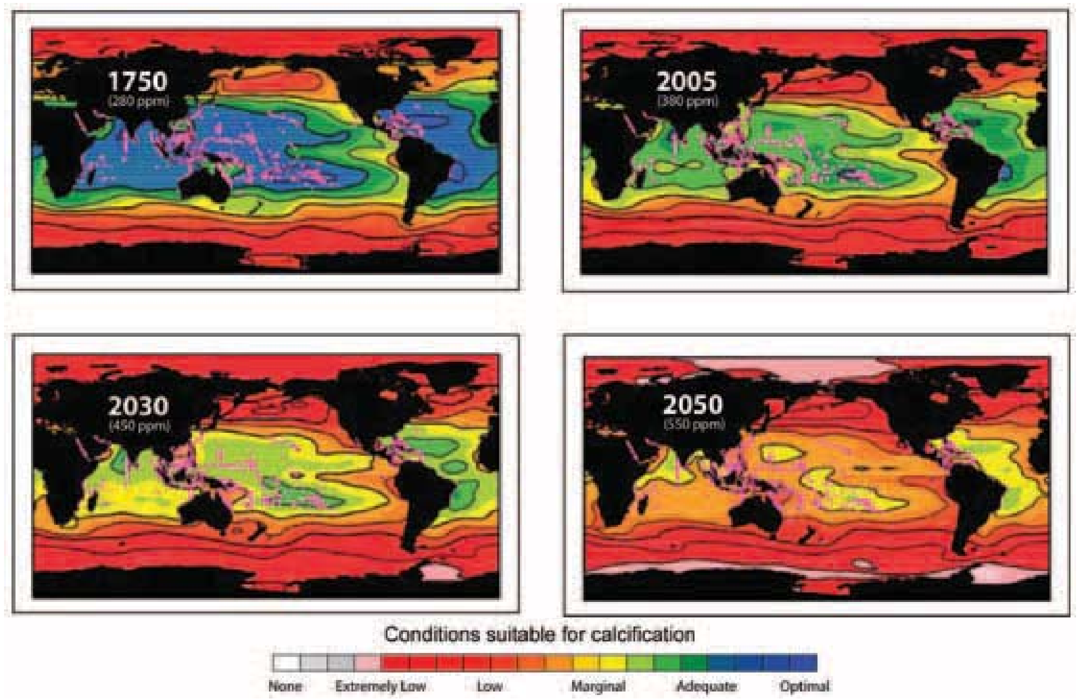


Figure 5.6 **Predicted changes in conditions suitable for calcification**[15]

With continuing acidification of the oceans, the areas where conditions are suitable for the building of shells and skeletons will shrink and ultimately disappear. Coral reefs are shown as pink. (Modified by permission of American Geophysical Union. From Cao and Caldeira, 2008[16])

Projected vulnerabilities of groups of species and habitats based on global projections of climate variables highlight the variability of responses to climate change within the Great Barrier Reef ecosystem at different concentrations of atmospheric carbon dioxide[3 4 19] (figure 5.7). In summary:

- **400ppm** The frequency of severe bleaching is likely to increase, with rising summer temperatures leading to the dominance of more thermally tolerant species. Acidification is expected to be affecting the growth of coral species and coralline algae, which consolidates coral rubble into reef limestone. Seagrasses, seabed habitats and marine mammals are not expected to be affected.
- **450ppm** Severe mass bleaching is predicted to occur annually with 34 per cent (range = 0-68 per cent) of coral reefs above the critical limits for coral bleaching. Ocean acidification is likely to further affect the growth of most calcifying organisms. Coral reefs are expected to be increasingly dominated by fleshy and turf macroalgae. Islands and coastal habitats are likely to be experiencing changes as a result of rising sea levels.
- **500ppm** There is likely to be reduced density and diversity of corals, impacting on other species (especially fish) that are reliant on coral reef habitats. Seabirds are likely to experience reduced foraging success, increasing the failure of nesting. Marine mammals and seagrasses are likely to be affected by the flow-on effects of increasing sea temperatures.
- **550ppm** Critical limits for coral bleaching would be reached for 65 per cent (range = 0-81 per cent) of coral reefs. Coral reef habitats are expected to erode rapidly. Increasing ocean acidity is likely to also cause composition shifts in plankton and impacts to calcareous forms of macroalgae such as *Halimeda*.
- **No mitigation** In the absence of mitigation, 99 per cent (range = 85-100 per cent) of coral reefs would be above the critical limits for coral bleaching.

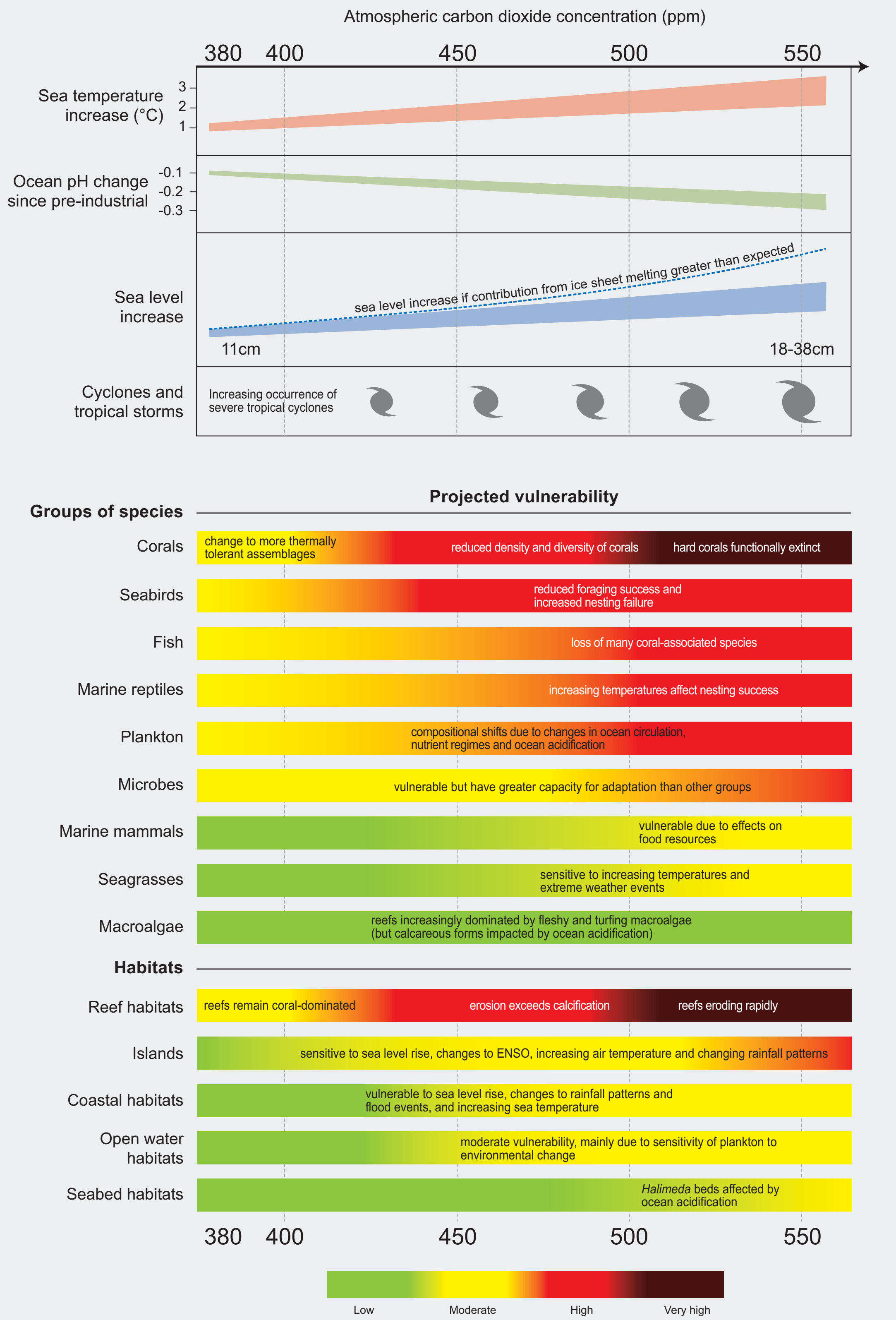


Figure 5.7 | **Projected vulnerabilities of components of the Great Barrier Reef ecosystem to climate change**

This diagram shows projected vulnerability across a range of carbon dioxide concentrations. Changes in sea temperature, pH and sea level are indicative only, intended to demonstrate the scientific uncertainty around the likely values. The worst case scenario presented (550ppm) is equivalent to the Intergovernmental Panel on Climate Change scenario B1which was predicted to be reached by about 2100. (Figure adapted from values presented in IPCC 2007[1], Hoegh-Guldberg *et al.* 2007[4], and Johnson and Marshall[19])

5.2.3 Implications of climate change for regional communities

The Great Barrier Reef ecosystem provides a substantial foundation for economic activity and social well being (Chapter 4). Therefore, changes to the ecosystem because of climate change are likely to have serious implications for dependent industries and communities.

Climate related changes to the ecosystem are expected to seriously affect Reef-based industries and communities.

There are widespread differences of understanding about climate change and its likely impacts among individuals and communities who live by the Great Barrier Reef or who depend on the ecosystem for a livelihood. A 2007 survey[20] about threats to the Great Barrier Reef identified a difference in perceptions between local communities and residents of the southern capital cities of Melbourne, Sydney and Brisbane. Members of the local communities saw water pollution as the biggest threat to the Great Barrier Reef followed by climate change whilst residents of the southern capitals saw climate change as the single biggest threat followed by water pollution.

Commercial marine tourism Climate change has major consequences for most aspects of marine-based tourism. Commercial marine tourism operators are concerned about the impacts of climate change on their businesses and livelihoods. Some key areas identified by the industry include: degradation of reef sites due to coral bleaching, poor recovery of bleached sites as a result of other stresses such as water pollution, and more extreme weather events.[21] Another major concern is the potential for the Great Barrier Reef to lose its marketing appeal as a high-quality reef destination[21], especially because of the profile given to climate change impacts on the Great Barrier Reef.

Climate related changes to the ecosystem could affect patterns of use of the Great Barrier Reef and visitor satisfaction.

However, declining reef condition may not translate directly to declining tourist numbers because degraded reefs may remain attractive and there may be small areas of reefs capable of supporting tourist activities even if widespread areas have deteriorated. Notwithstanding these factors, there may be a decline in visitor satisfaction in the long-term.

Fishing It is likely that the biological, social and economic aspects associated with commercial and recreational fishing may be highly sensitive to climate change. New opportunities may be created as the distribution of fishes shifts southward. In addition, there is potential for adaptation measures to be employed by some sectors of the industry.[22]

Fishers will have to contend with projected changes in fish abundance and survivorship (including fish larval development[23 24], although such studies are in preliminary phases[25]), fish size and distribution (e.g. homing ability) as well as changes in cyclonic and storm activity.[26] Fishers may also have to modify their fishing practices in response to disruptions to shallow-water nursery grounds (such as mangroves and seagrass beds), loss of coral reef habitats from more severe coral bleaching, altered species distribution from the effects of sea level rise and increasing sea temperatures.

Scientific research Climate change is now a focus of virtually all research symposia, attracting the attention of the greatest number of reef research scientists in history. During this process, the Great Barrier Reef is maintaining its historical role as the world's most studied coral reef ecosystems. There is no one dominant field of study, however a high proportion of research is directed towards documenting change, as well as understanding ecosystem function from biological and environmental points of view. Less well studied are the social and economic ramifications of climate change to regional communities and reef-dependent industries.

Ports and shipping Climate change is likely to result in rising sea levels, and more intense storms and cyclones. The likely impacts on ports and shipping include increased costs of shipping resources, increased energy demand and demand for construction techniques that reduce the likelihood of damage to infrastructure. Key factors that affect vulnerability and adaptive capacity of a settlement such as a port include the type, size and location of infrastructure, the socio-economic characteristics of surrounding regional communities and institutional arrangements to respond to the effects of climate change.[27]

Traditional use of marine resources Traditional Owners are concerned about rising temperatures altering the seasonality and availability of marine resources as well as the potential loss of totemic species, such as dugongs and marine turtles, and the possible displacement of coastal Traditional Owner communities due to rising sea levels.[26]

5.3 Coastal development

The Great Barrier Reef has always attracted people to live and establish their livelihoods in its catchment. Aboriginal and Torres Strait Islander Traditional Owners were the first to live along the coast. The Great Barrier Reef was believed to be first sighted by Europeans in the 1600s and they established their first settlements in the catchments in the 1850s (figure 5.8).

The term coastal development includes all the development activities within the Great Barrier Reef catchment, such as rural land use, mining and industry, population growth, urban infrastructure and port development. Increasing coastal development and consequent impacts on coastal ecosystems remains an ongoing factor affecting the long-term health and resilience of the Great Barrier Reef ecosystem. The effect of coastal development on water quality entering the Great Barrier Reef is discussed in Section 5.4.

5.3.1 Current state and trends of coastal development

Catchment land uses The major land uses of the rural areas in the Great Barrier Reef catchment are grazing, cropping, dairying, horticulture, forestry and protected areas (figure 5.9). Cattle grazing is the most extensive land use, undertaken mainly in the larger catchments. The smaller more coastal catchments support more intensive agricultural uses such as cropping and forestry (figure 5.10). The area of catchment that has become intensively farmed, especially for sugar, has quadrupled over the last 150 years (figure 5.11).

The Great Barrier Reef catchment is rich in mineral resources and has long supported significant mines and industry.[38] Prior to its prohibition in 1975, there was some mining of areas within the Great Barrier Reef Region, in particular of limestone,

In the past 150 years, agricultural land use in the catchment has become more intensive.

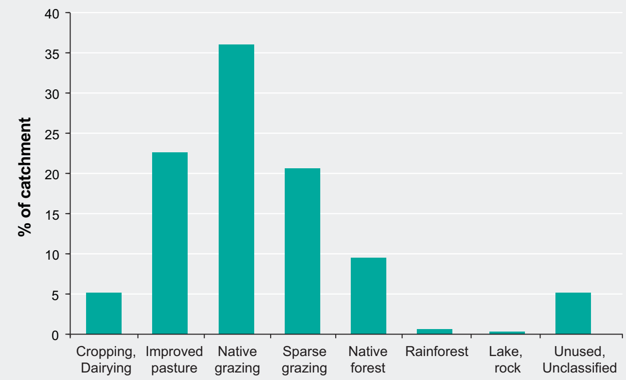


Figure 5.9 **Major land uses of rural areas in the Great Barrier Reef catchment[28]**

Grazing accounts for nearly 80 per cent of land use in the Great Barrier Reef catchment.

1600s	Possible first sighting of the Great Barrier Reef by Europeans.
1770	Great Barrier Reef visited by Captain James Cook on his first voyage.
1850s	First European settlement in the Great Barrier Reef's catchment. Cattle and sheep grazing commenced in the Great Barrier Reef catchment.
1860s	Intensive agriculture (sugar cane) commenced in the Great Barrier Reef catchment. First gold rush in the Great Barrier Reef catchment. Mining for guano/rock phosphate commenced on Great Barrier Reef islands and cays.
1890s	Gold rush ended.
1930s	Introduction of new drought and tick-resistant cattle into the Great Barrier Reef's catchment.
1940s	Guano/rock phosphate mining on Great Barrier Reef islands ended.
1974	Release of the Royal Commission Report on exploration and drilling for petroleum in the Great Barrier Reef.
2003	Population in the Great Barrier Reef catchment reaches 1 000 000.

Figure 5.8 **Main events in the European settlement of the Great Barrier Reef catchment**

Grazing, agriculture, mining and urban settlement are key features of the use of the Great Barrier Reef catchment.

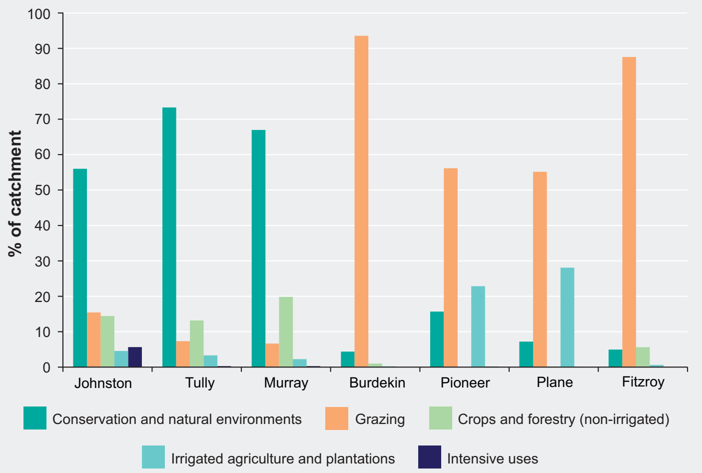


Figure 5.10 Comparison of major rural land uses among catchments of the Great Barrier Reef

Grazing is mainly restricted to the drier catchments in the central and southern Great Barrier Reef. (Data from the Queensland Department of Natural Resources and Water[29 30 31 32 33 34 35])

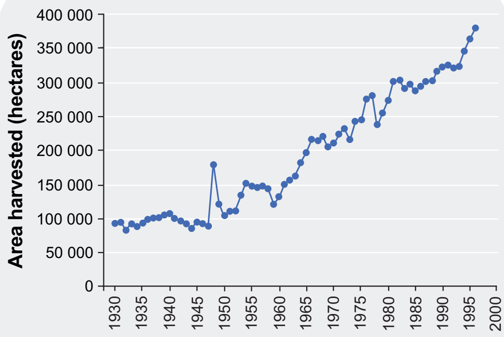


Figure 5.11 Area of the Great Barrier Reef catchment used for sugar production[36]

More of the Great Barrier Reef catchment is being intensively farmed. For example, the area of land used for sugar cane production in the Great Barrier Reef catchment has increased steadily since the mid-twentieth century. The land area under cane production and the tonnage of cane harvested has remained static between 1998 and 2008.[37]

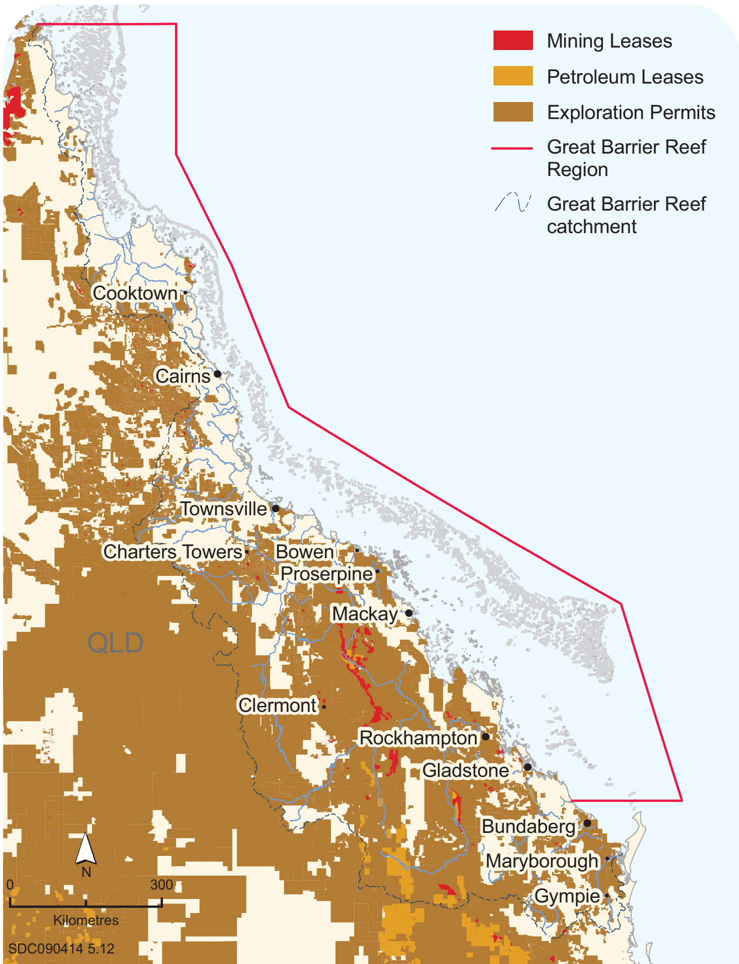


Figure 5.12 Mining leases and exploration areas[40]

Mining exploration permits cover much of the land in the Great Barrier Reef catchment and beyond.

coral and guano.[39] Gold mining started in the Great Barrier Reef catchment in the 1860s. Over the 150 years of mining in Queensland, 53 000 mining leases have been granted, with more than 3000 current in Queensland as at October 2008 (figure 5.12).[38] There are currently hundreds of active mines. The largest mines in the Great Barrier Reef catchment are coal mines inland from Mackay.

Expenditure on mineral and petroleum exploration in Queensland and throughout Australia has gradually increased in recent years (figure 5.13), as has the recognition of the need to ensure proper rehabilitation of mine sites, including abandoned sites (Section 5.4.1).[41]

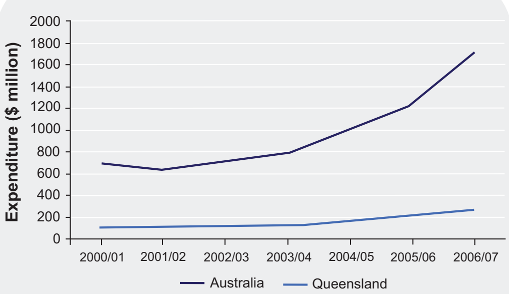


Figure 5.13 Expenditure on minerals exploration, 2001-2007[42]

Expenditure on mineral and petroleum exploration in Queensland and throughout Australia increased throughout the period from 2001 to 2007.

Patterns of catchment land use may change in the future because of changing global economic conditions, shifting global markets and technological developments such as biofuels and coal-gas projects.

Population growth There are 72 coastal urban centres (i.e. populations greater than 200) directly adjacent to the Great Barrier Reef coast, with four centres of populations greater than 50 000.[43] Mining and industrial activity has been driving population growth throughout the Great Barrier Reef catchment at rates faster than the Australian average, especially along the coast (figures 5.14 and 5.15). The current population of the Great Barrier Reef catchment is about 1 115 000; it is expected to grow to 1 577 000 by 2026 at an average annual growth rate of nearly two per cent.[44]

This would be a 40 per cent increase in the population living in the Great Barrier Reef catchment by 2026 with the majority expected to live on or near the coast. While present development affects only a small portion of the coast, a significant portion of coastal land has freehold status, providing potential for intensification of development activities. In many areas, this growth is severely stretching local government infrastructure and facilities and leading to degradation of coastal ecosystems.[39 45 46 47 48 49]

The increasing number of people living close to the Great Barrier Reef means increasing recreational use of the marine area. Boat ownership is increasing steadily within the catchment (figure 5.16). This has driven an increased demand for boating facilities such as marinas, moorings and boat ramps, often located within the Great Barrier Reef Region or adjacent coastal habitats.

Urban infrastructure Population growth in coastal areas leads to an increase in infrastructure and services such as roads, water, sewerage and power. If poorly planned and implemented, these constructions can further modify the coastal environment and cause sedimentation, water quality issues and drainage impacts.

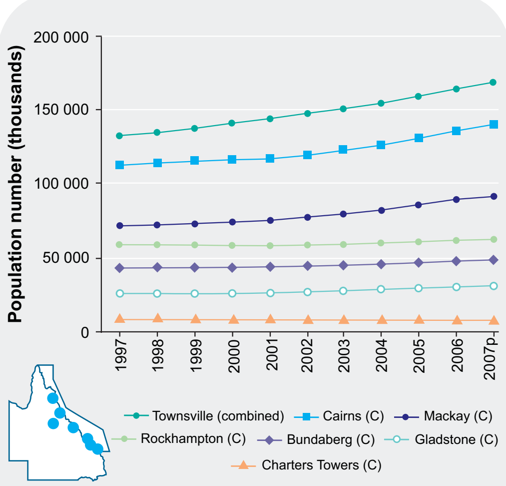


Figure 5.14 Population growth in major urban centres of the Great Barrier Reef catchment[44]

Over the last decade, populations have grown steadily in urban centres adjacent to the Great Barrier Reef. 'p' means preliminary data collected after the 2006 census. Townsville (combined) represents the previous two cities of Townsville and Thuringowa, which were amalgamated in March 2008.

Coastal Queensland is one of the fastest growing regions in Australia.

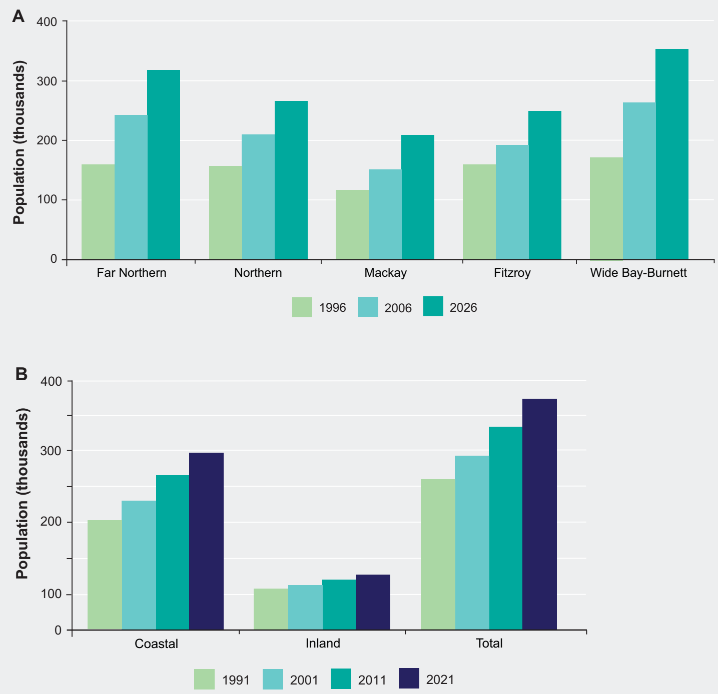


Figure 5.15 Population growth and predictions in the Great Barrier Reef catchment[44]

Populations are predicted to continue growing in the statistical divisions within the catchment (A), especially immediately adjacent to the Great Barrier Reef (B).

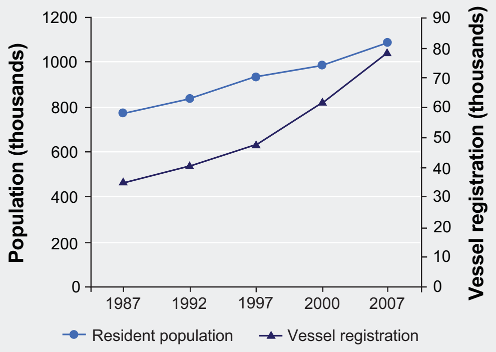


Figure 5.16 Growth in vessel registrations in areas close to the Great Barrier Reef[50]

As the population has grown in areas close to the Great Barrier Reef, so has the number of vessels registered.

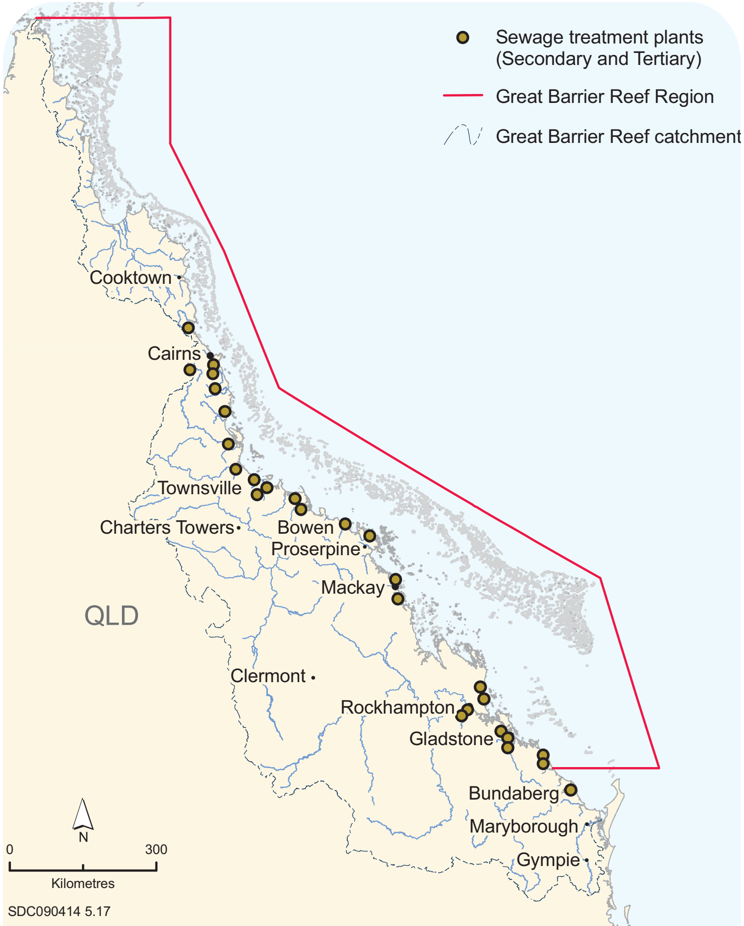


Figure 5.17 Sewage treatment plants along the Great Barrier Reef coast[53]

Sewage discharge contributes a very small proportion of nutrients entering the Great Barrier Reef. Tertiary treatment of sewage decreases nutrient inputs into the marine environment and is being progressively implemented for all coastal sewage adjacent to the Great Barrier Reef. All island treatment plants (not shown) discharging directly into the Great Barrier Reef Marine Park already meet tertiary treatment standards.

Sewage treatment plants occur along the length of the southern and central Great Barrier Reef coast (figure 5.17). An increasing proportion of sewage is tertiary treated or recycled, partly to reduce the direct impacts on the Great Barrier Reef. Under Queensland Government policy all coastal sewage treatment plants that discharge into the marine environment must meet the most stringent treatment standards (i.e. tertiary treatment) by 2010.[51] Treatment plants on islands discharging directly into the Great Barrier Reef Marine Park already meet this standard under Great Barrier Reef Marine Park Authority policy. Sewage discharge contributes only between three and four per cent of the total nitrogen load and less than one per cent of the total phosphorus load discharged annually into the Great Barrier Reef. As populations grow, so will the need to address increases in sewage outputs.[52]

There is good evidence of community awareness of the impact of urban development on the Great Barrier Reef. The Reef Guardian Council program has been designed to recognise and foster environmental stewardship for the Great Barrier Reef from local government and the general community by raising awareness and encouraging best management practice in local government activities. Local governments, especially the Reef Guardian Councils, are developing plans to control the quality of runoff within urban areas and many have installed litter traps.

Importantly, more than 180 schools participate in the Reef Guardian Schools Program, a major component of which promotes awareness of environmental issues such as litter damage.

Port development The twenty-first century has been a period of great expansion in ports and shipping activity in the Great Barrier Reef. Mining and industrial activity is one of the major drivers of that growth. There are proposals for significant expansion (such as new berths, dredged channels and land-based development) in at least seven of the 10 major trading ports along the Great Barrier Reef coast. For example, in 2008 the Port of Gladstone anticipated being able to accommodate up to 300 million tonnes of export product within the next 50 years (a six-fold increase) requiring existing wharf centres to be reorganised, new berths constructed and a duplicate shipping channel created.[54]

Success in fostering action in Queensland schools

The Great Barrier Reef Marine Park Authority's Reef Guardian Schools Program encourages schools to commit to the protection and conservation of the World Heritage listed Great Barrier Reef. At least 180 Reef Guardian Schools are committed to protecting and preserving the marine environment for the future by developing initiatives to help all Australians live, work and play in a sustainable way. Schools participating in the program focus on management of resources, on-ground projects in the school and community and education of the wider community. The program strengthens links between schools, the community, government, businesses, environmental groups and the Great Barrier Reef Marine Park Authority by enabling teachers, students and members of the community to be environmentally active and work together as committed Reef Guardians.

For some ports such as Abbot Point, shipping activity has been predicted to increase about fivefold over the next 10 years mainly in response to mining exports (figure 5.18). The realisation of these predictions will principally depend on recent changes to global economic conditions.

5.3.2 Vulnerability of the ecosystem to coastal development

The predominant impact of coastal development on the Great Barrier Reef ecosystem is the loss of both coastal ecosystems and connectivity between ecosystems.[52]

Historically, the most significant impacts of coastal development on coastal ecosystems in the Great Barrier Reef catchment has been the loss of coastal wetlands and adjacent dune systems. It has been variously estimated that 70 to 90 per cent of coastal wetlands have been lost[45] and many vegetation types on the remaining dune systems are now rated as 'of concern' or 'endangered'.[51 55] At the same time, extensive areas of habitats that support the Great Barrier Reef ecosystem have been infilled, modified or cleared (figure 5.19). All these habitats are important as feeding and breeding grounds for marine species and as sediment traps and nutrient filters for water entering the Great Barrier Reef.

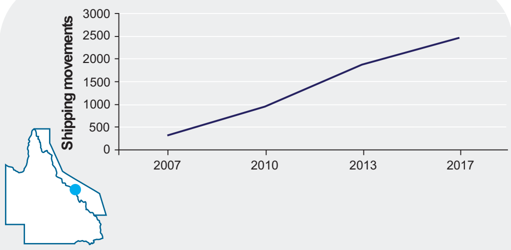


Figure 5.18 Predicted increases in shipping, Abbot Point, 2007–2017

Abbot Point is an example of likely increases in shipping over the next 10 years, driven by mining activity. (Information from Maritime Safety Queensland)

Mining and industry is fuelling growth in ports and shipping.

Coastal development is affecting coastal habitats that support the Great Barrier Reef and connectivity between habitats.

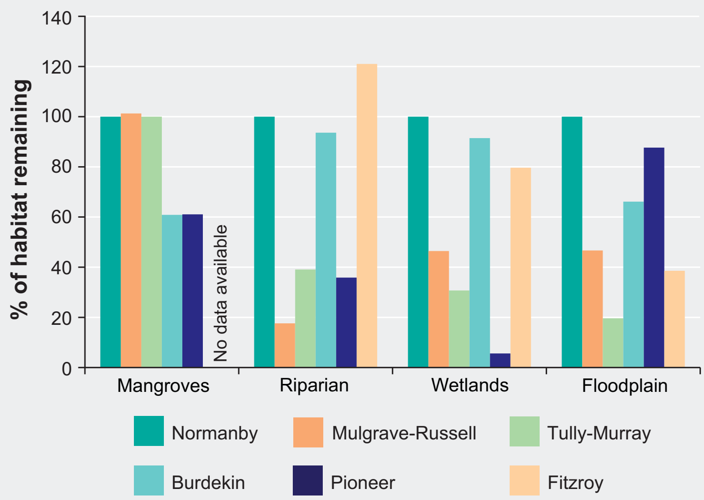
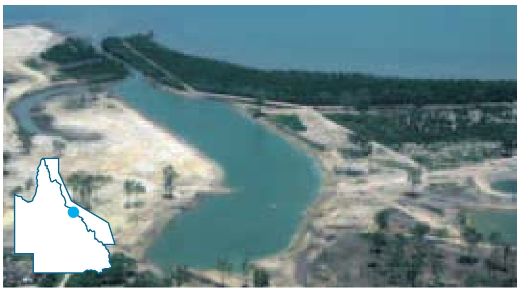
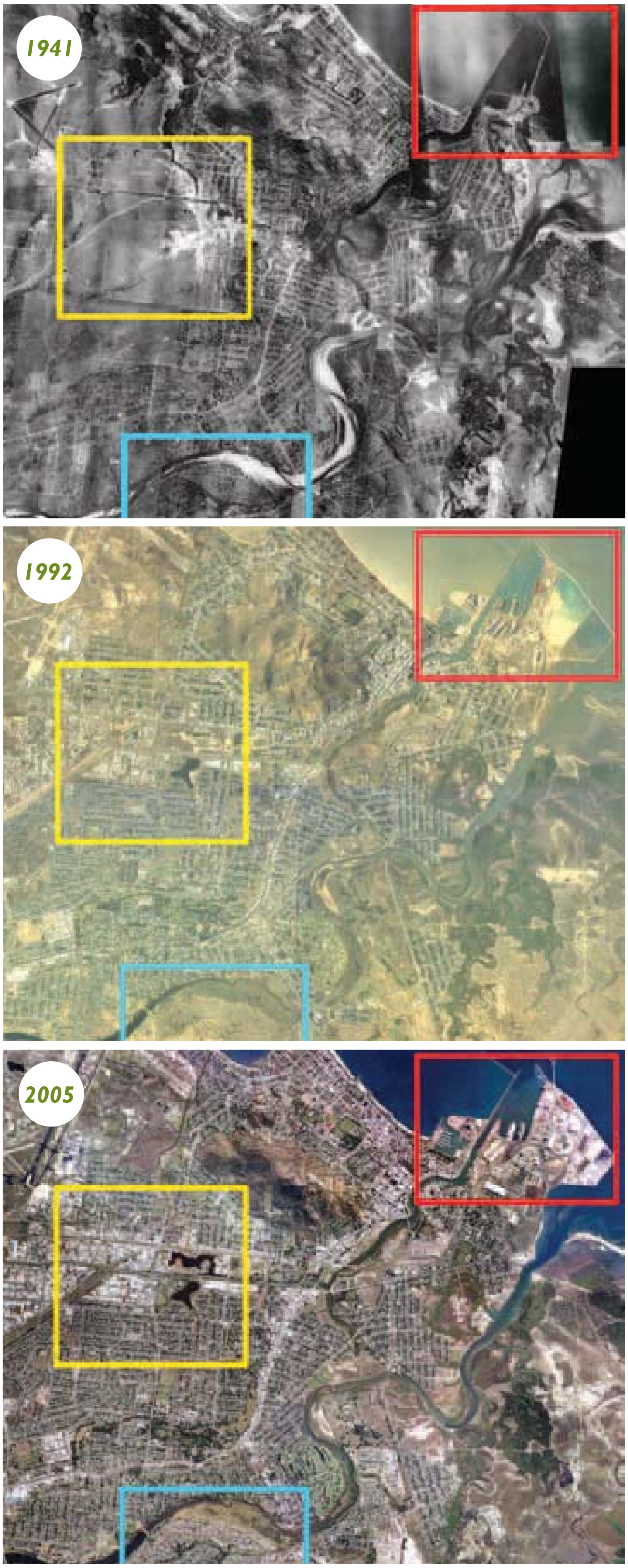


Figure 5.19 Loss of habitats that support the Great Barrier Reef[28]

Important coastal habitats have been largely lost from some major river systems within the Great Barrier Reef catchment particularly in more developed catchments such as the Mulgrave-Russell, Tully-Murray and Pioneer. The percentage of habitat remaining is calculated in comparison to the predicted area of each habitat prior to European settlement.



The natural environment and drainage patterns are substantially changed in most coastal habitats altered for urban expansion such as this development near Cardwell.



Expansion of urban areas in Townsville. Urban centres such as Townsville have expanded rapidly over the last 65 years, especially in the last decade. This has meant the modification of many wetland habitats and drainage patterns, the reclamation of coastal areas and the expansion of urban settlement. (Images courtesy of Townsville City Council)

In addition, many natural drainage patterns have been disturbed, disrupting connections between freshwater and marine environments.

Much of the supporting infrastructure for mining and exploration activity is located on the coastal fringe and, in the last two decades, major State Development Areas have been declared in Gladstone (1993), Townsville (2003), Abbot Point (2008) and Gladstone/Curtis Island (2008).[56]

Many coastal habitats, such as those at the location for this refinery near Gladstone, have been affected by industrial development.

In the Gladstone region, for example, industrial development has affected extensive coastal wetlands, has reclaimed beach and mangrove habitats and there are current proposals to modify the environment of nearby Curtis Island[57], part of the Great Barrier Reef World Heritage Area. In 2008, decisions by both the Queensland and Australian Governments regarding specific mining and infrastructure proposals have increased protection of the internationally important wetlands at Shoalwater and Corio Bay and the nationally significant Goorganga wetlands near Proserpine. Other infrastructure proposals (e.g. existing and planned port expansions) continue to have the potential to clear or infill coastal habitats that support the Great Barrier Reef ecosystem.

The litter transported to the ocean by urban runoff may be ingested by wildlife such as marine turtles and seabirds or cause entanglement especially as the feeding strategies of some animals means that they are naturally attracted to areas of debris. Ingestion may interfere with feeding and cause intestinal blockages, poisoning, or other injuries that may result in death. Debris on beaches can interfere with a marine turtle's ability to dig an egg chamber or may prevent hatchlings from reaching the sea.[58] Marine mammals are occasionally found dead on beaches having ingested or become entangled in debris.[59]

The projected increase in recreational use as a result of population growth is likely to result in greater localised effects on the ecosystem (Section 4.6.3).

5.3.3 Implications of coastal development for regional communities

It is expected that an increasing coastal population will increase the economic value of reef-based activities in the long-term. More people living close to the Great Barrier Reef means more people will use the Great Barrier Reef, especially given the increasing ownership of boats and recreational equipment.

At the same time, this increasing use can be expected to increase congestion at popular recreation locations and competition for preferred sites. To date there is no evidence that increasing numbers of recreational users is affecting the satisfaction of people visiting the Great Barrier Reef (figure 4.24).

The predicted increases in shipping activity and the expansion of ports will potentially result in more adverse interactions with other commercial and recreational vessels using the area.

5.4 Catchment runoff

One of the major impacts of coastal development (both urban and rural) is changes in the quality of freshwater entering the Great Barrier Reef from its catchments. Therefore it is discussed separately from the other impacts of coastal development covered in Section 5.3.

5.4.1 Current state and trends of catchment runoff

The Great Barrier Reef receives the runoff from 38 major catchments which drain 424 000 km^2 of coastal Queensland (figure 5.20). Over the last decade, the declining quality of water entering the Great Barrier Reef has been recognised as a major threat to the ecosystem.[60]

Freshwater flows The catchments that deliver freshwater to the marine environment of the Great Barrier Reef can be loosely divided into:

- Coastal catchments, such as those of the Tully River and Pioneer River, which provide a continuous flow of freshwater to the Great Barrier Reef from relatively small catchments. These catchments support areas of intensive agriculture.
- Large catchments, such as the Burdekin River and Fitzroy River, which drain inland areas dominated by grazing activities. River flows in these catchments tend to be highly seasonal and dominated by flood events.

Flood events in the wet season deliver a large proportion of the nutrients and sediments onto the Great Barrier Reef. Concentrations of dissolved inorganic nitrogen, dissolved inorganic phosphorous and suspended sediment are all many times higher during flood events than at other times

Most sediment entering the Great Barrier Reef comes from catchments with large pastoral areas.

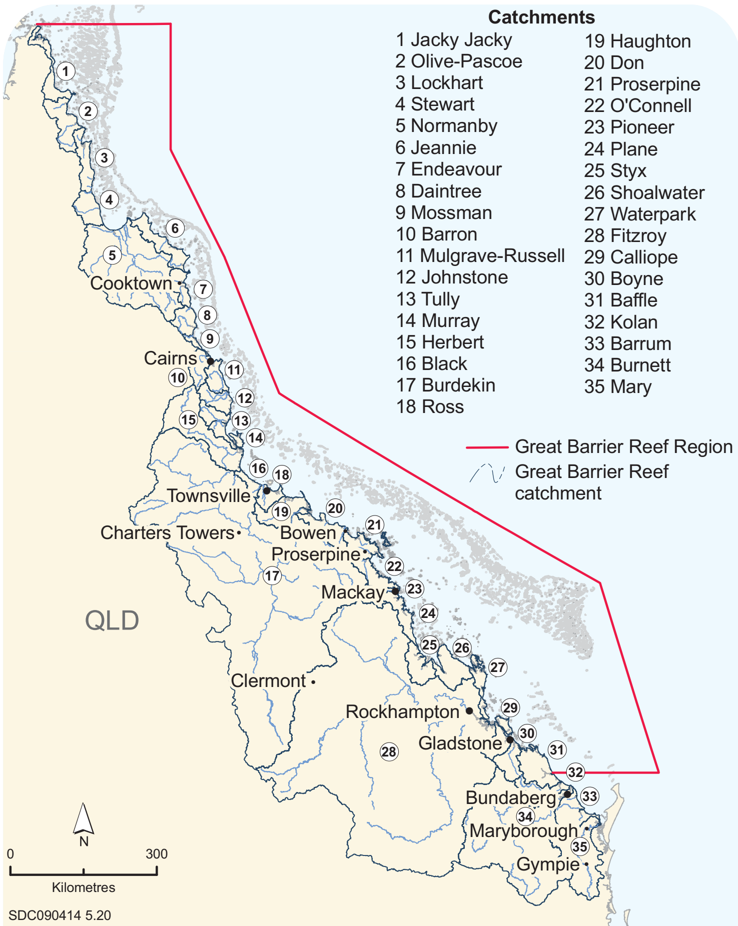


Figure 5.20 **The Great Barrier Reef catchment**

All the runoff from the adjacent catchments eventually finds its way to the Great Barrier Reef. (Data from Department of Employment, Economic Development and Innovation).

Intensification of rural land use increases nutrient loads entering the Great Barrier Reef.

Most of the sediments and nutrients entering the Great Barrier Reef are delivered during flood events such as here at Taylors Beach (the outlet for the Herbert River) near Ingham.

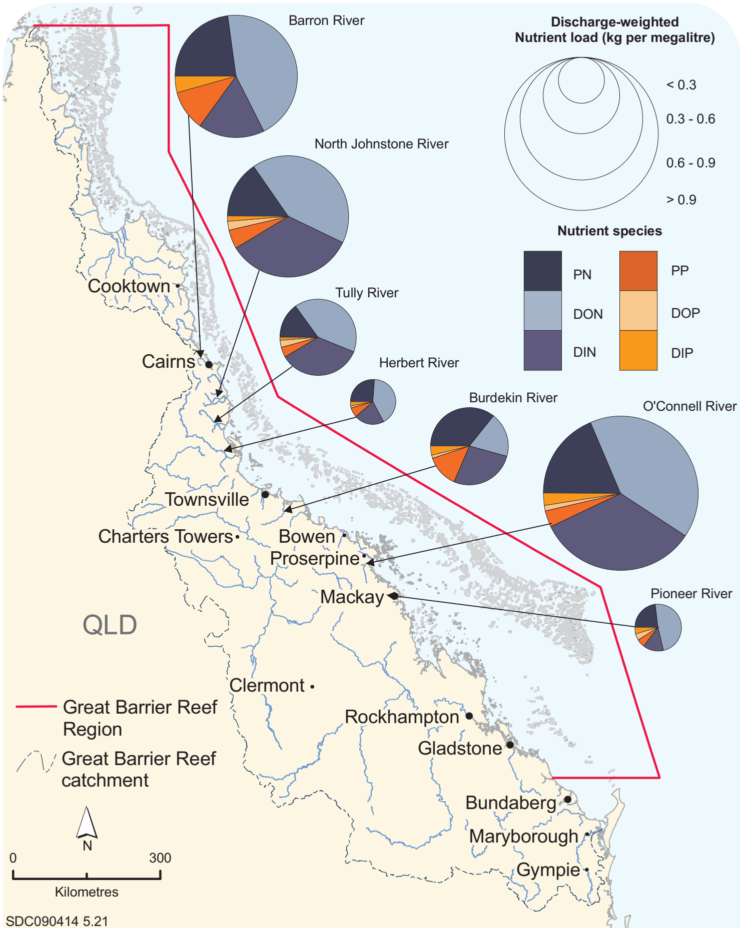


Figure 5.21 | Nutrient loads entering the Great Barrier Reef, 2005 dry season and 2005/06 wet season[62]

Most nutrients flowing onto the Great Barrier Reef are from the wetter, more intensively cropped catchments (Barron, North Johnstone and O'Connell Rivers). PN - particulate nitrogen, DON – dissolved organic nitrogen, DIN – dissolved inorganic nitrogen, PP – particulate phosphorous, DOP – dissolved organic phosphorous, DIP – dissolved inorganic phosphorous.

Nutrients Under natural conditions, the rivers that flow into the Great Barrier Reef provide nutrients to the marine ecosystem. However, the total nutrient load delivered is now greater than before agricultural development, with dissolved inorganic nitrogen and phosphorous entering the Great Barrier Reef at greatly enhanced levels, (two to five times greater for nitrogen and four to ten times greater for phosphorus relative to pre-European settlement).[61] Much of the nutrient load is derived from areas of high intensity land use, for example in the Wet Tropics area around Cairns and the Mackay/Whitsunday region (figure 5.21).

Nitrogen and phosphorus are the two most ecologically significant nutrients flowing into the Great Barrier Reef and are present in a range of forms.[62] Increased loads of particulate nitrogen are derived from intensive agriculture as well as low intensity grazing and forestry (figure 5.22). This form of nitrogen originates principally from hill slope, gully and bank erosion. The input of dissolved inorganic nitrogen is substantially higher from land under intensive agriculture than from areas of less intensive land use.

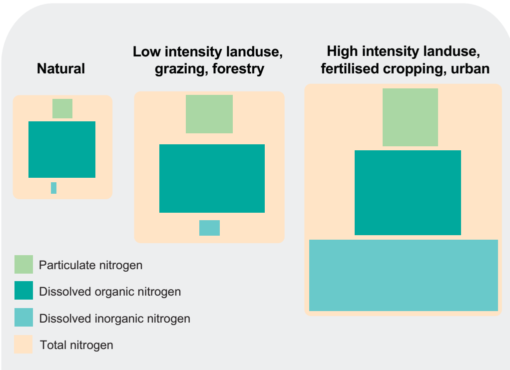


Figure 5.22 | Relative loads of nitrogen from different land uses in the Great Barrier Reef catchment[63]

The load of total nitrogen delivered to the Great Barrier Reef from its catchment is mainly derived from high intensity land use, fertilised cropping and urban areas. In particular, high intensity cropping is the major contributor of dissolved inorganic nitrogen. Only a small proportion of the load is derived from natural areas and almost none of the dissolved inorganic nitrogen.

Dissolved inorganic nitrogen is immediately available to marine organisms (Section 3.3.1) and, historically, only small quantities have entered the marine environment. Today, the main source of dissolved inorganic nitrogen is fertilisers in runoff (figure 5.23).

Sediments The total annual average sediment load discharged into the Great Barrier Reef waters (Section 3.2.4) is estimated to have increased four to eight-fold since European settlement[66], the bulk coming from catchments that have large grazing areas (figure 5.24). This is due mainly to increased soil erosion in areas cleared to establish pasture, exacerbated by overgrazing.[66] Soil erosion in cane farming areas has reduced since burnt cane harvesting was replaced by green harvesting and trash blanketing.[67]

Over the past 150 years, sediment inflow onto the Great Barrier Reef has increased as a result of extensive forest clearing, especially the clearing of lowland rainforests and wetlands for sugar cane and the clearing of dryland forest for cattle.[28] The latter, especially, creates sheet erosion where the nutrient-rich uppermost layer of topsoil is washed into rivers during heavy rain, a phenomenon exacerbated by the introduction of drought-resistant breeds of cattle capable of heavy grazing of grassland during the dry season.

Pesticides The use of pesticides (including herbicides, insecticides and fungicides) continues within the Great Barrier Reef catchment particularly in areas under crop cultivation. Currently, seven herbicides (diuron, atrazine, ametryn, simazine, hexazinone, 2,4-D, and tebuthiuron) are in widespread use in the catchment.[68]

Pesticides are being widely detected in the waters and animals of the Great Barrier Reef (Section 3.3.2) and in waters in its catchment (figure 5.25). Their presence is of concern as they can accumulate in marine plants and animals. The residence time of pesticides in the environment varies with half lives (the time taken for half the original amount to break down) ranging from five days to about 15 months[68] for the most commonly used pesticides.

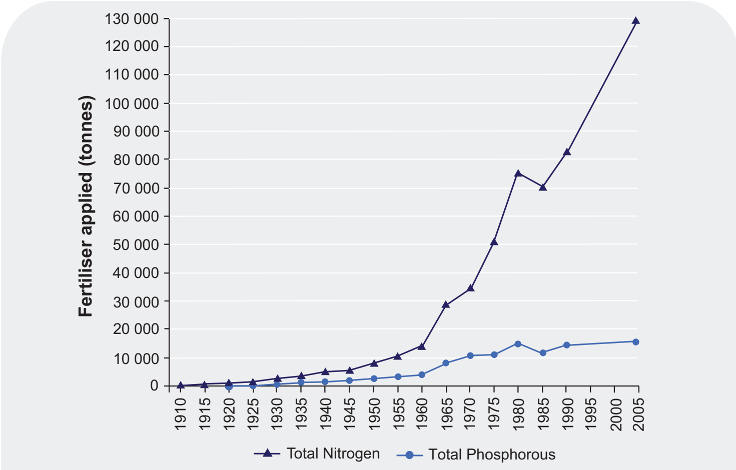


Figure 5.23 **Fertiliser use in the Great Barrier Reef catchment[61 64 65]**

Although individual farmers may be making significant reductions in fertiliser use, the total amount applied continues to increase. However, within the Great Barrier Reef ecosystem, recent monitoring of five nutrient parameters (total dissolved nitrogen, total dissolved phosphorus, particulate nitrogen, particulate phosphorus, suspended solids) showed generally decreasing patterns since the early 2000s (Section 3.3.1).

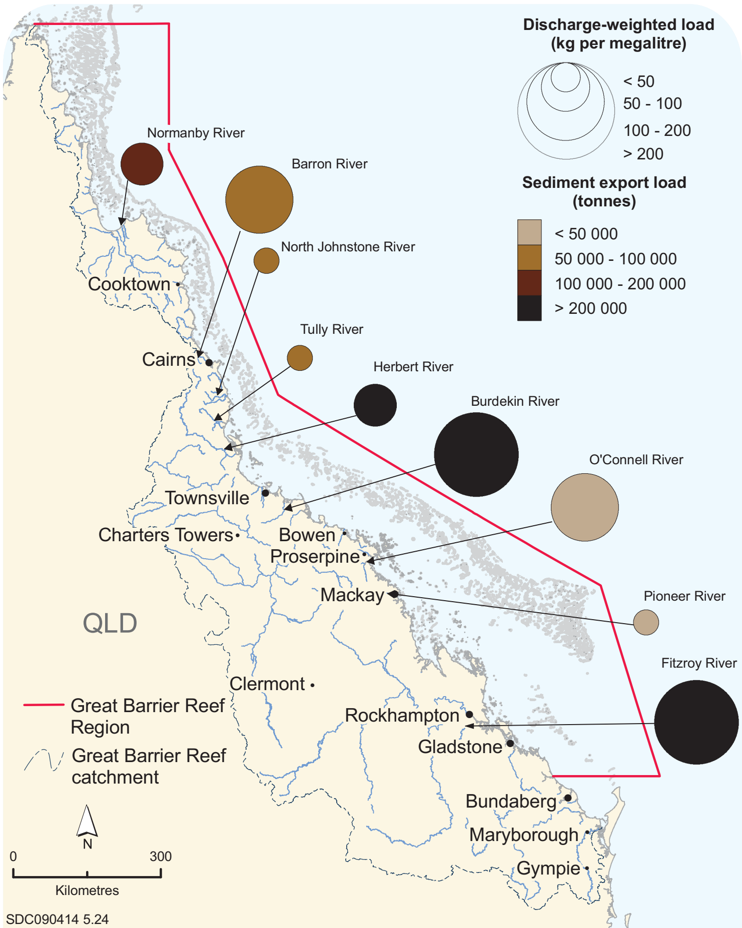


Figure 5.24 **Sediment loads entering the Great Barrier Reef, 2005/06 wet season[62]**

Catchments with large pastoral areas (Herbert, Burdekin and Fitzroy Rivers) deliver the most sediments to the Great Barrier Reef, in the highest concentrations.

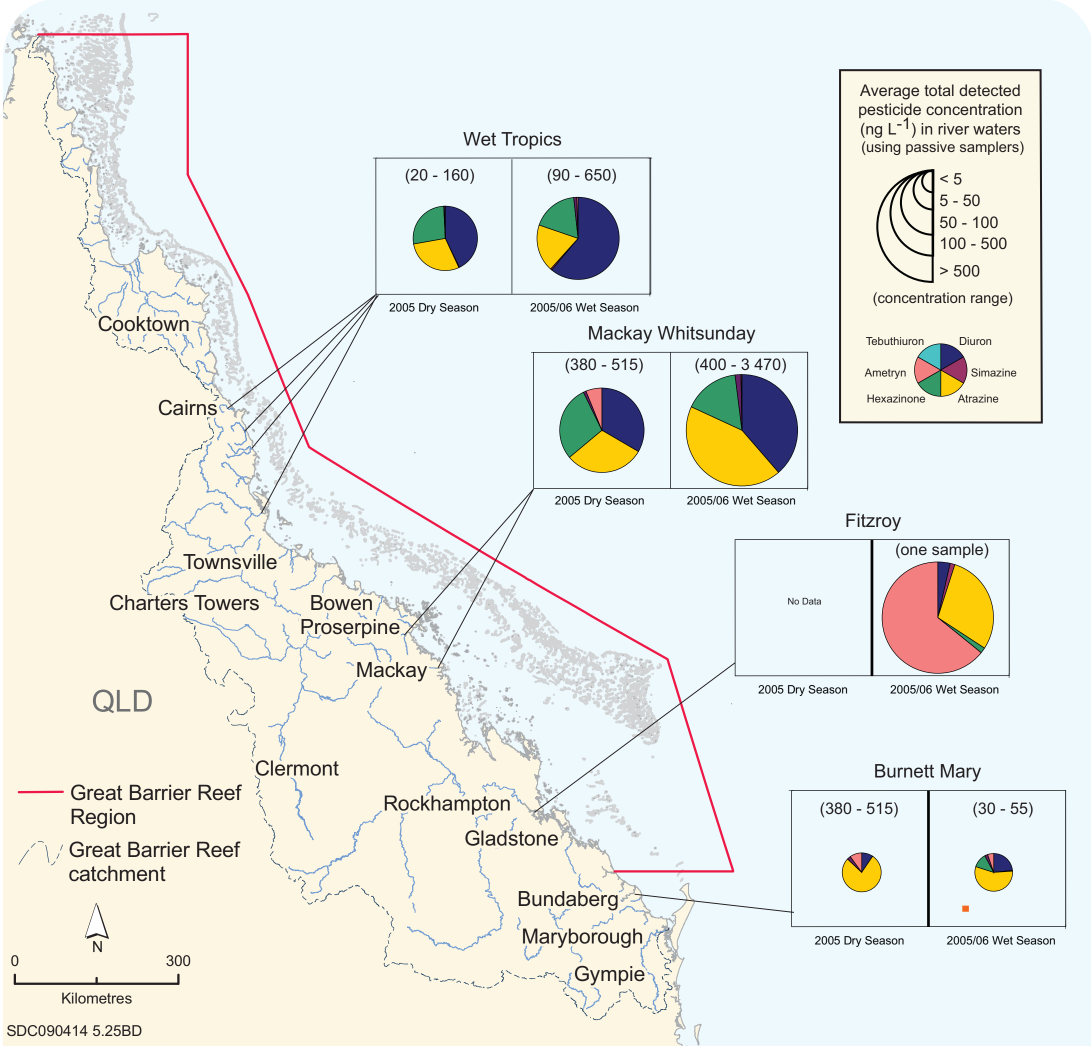


Figure 5.25 Pesticides entering the Great Barrier Reef, 2005 dry season and 2005/06 wet season[62]

Pesticides, including herbicides and fungicides, have been widely detected in waters entering the Great Barrier Reef. They are not naturally part of the ecosystem and their impacts are poorly understood. No data is available for the Burdekin.

Mining Historically, there have been extensive small-scale mining operations throughout much of the Great Barrier Reef catchment. Rehabilitation of mining sites, including the quality of water coming from them, is now part of the management responsibility of the mining industry.[38] Addressing the quality of water coming from mines and industrial sites is acknowledged as an essential component of a sustainable mining industry.[38] The ongoing impacts of mine sites relate to the degraded quality of water flowing from mining voids and underground passageways (for example elevated concentrations of heavy metals, arsenic, salts, acid-leachate and sediments).[41] These materials are known to contaminate underground water supplies and some have been detected on the Great Barrier Reef.[48] Thus, environmentally-sound mine management and effective rehabilitation of mined areas is essential to the limiting of long-term threats.

Water barriers Dams, weirs and drainage in most catchments have altered freshwater flows into the Great Barrier Reef (Section 3.2.3). This infrastructure can have a number of adverse effects including alteration in the timing and extent of major flows and restricting connectivity between marine and freshwater habitats.

In the Great Barrier Reef catchment, most dams and weirs capture water during the wet season and release it for use during the naturally dry times of the year. Thus, flows from some rivers during wet seasons may be reduced by dams and weirs and when this water is used for irrigation during dry conditions, flows to the Great Barrier Reef may be increased.[48] Water thus released usually comes low in the depth profile of the dam where its temperature and chemistry (concentration of dissolved oxygen for example) is significantly different from that in natural river flows.

Dams also act as sediment traps, for example the Burdekin Dam captures 60 to 80 per cent of the sediment (mainly the coarse fraction) of the Burdekin River's upstream tributaries. For other rivers, flows may be decreased during dry periods as a result of more water being retained and used in the catchment. In contrast, during flood events decreased vegetation[28], hardened surfaces and straightened channels means there is greater runoff and less water retention on the land.

In addition, the connectivity in the river system can be fragmented by water infrastructure, affecting the migration of species that travel either upstream or downstream to breed. For example, in the Fitzroy River between Rockhampton and Emerald there are six weirs[69], all of which may restrict the movement of fish species.

Land management Land owners, industries, natural resource management bodies and local, Queensland and Australian Governments are working to change land management practices with the aim of halting and reversing the decline in water quality entering the Great Barrier Reef. For example in the Tully and Murray River catchments, changes in land management practices have reduced the sediment load entering the Great Barrier Reef by over 50 per cent, from an estimated 263 000 tonnes each year before the 1970s to about 119 000 tonnes in 2005. In addition, between 2000 and 2007, there was an estimated 40 per cent reduction in the application of nitrogen as fertiliser to cane farm land in the catchment.[60] More widely, surveys show that the average application of nitrogen in banana production was reduced by about 40 per cent in the last decade, from an average of 519 kilograms/hectare/year in 1995 to 305 kilograms/hectare/year in 2005.

Nevertheless, the scientific consensus is that current management interventions are not effectively solving the problem.[60] In addition, the long lag time between changes made on the farm and downstream improvements means that it may be decades before any improvements in catchment runoff are reflected in cleaner water on the Great Barrier Reef itself.

Freshwater flows may be affected by changes in drainage patterns in the catchment.

5.4.2 Vulnerability of the ecosystem to catchment runoff

Increased concentrations of suspended sediments, nitrogen, phosphorous and agricultural chemicals are having significant effects on the ecosystems of the inshore Great Barrier Reef close to agricultural areas.[70]

Dissolved inorganic nutrients are quickly extracted from seawater by phytoplankton, bacteria and benthic organisms. However, chronically high levels can create ecological changes over larger areas as well as metabolic responses in most marine plants and animals.

Higher concentrations of these nutrients potentially lead to a decrease in coral diversity and an increase in macroalgae abundance (figure 5.26). Such a shift drastically affects the overall resilience of the ecosystem as a dominance of macroalgae reduces the chance for new hard corals to establish and grow.[70] The algae then out-competes coral trying to establish on the new substrate.[71] Algae may initially replace corals through external influences, such as temperature related mortality.

Increased concentration of suspended sediments and agricultural chemicals are having significant effects inshore, close to agricultural areas.

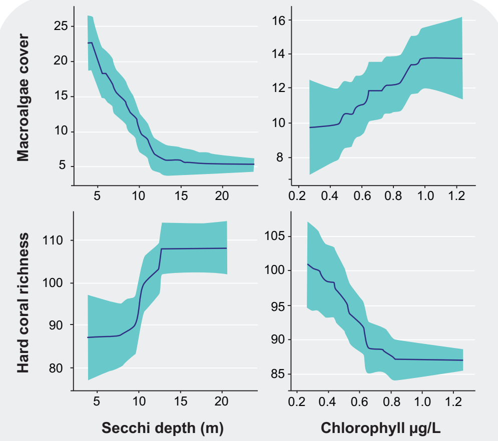


Figure 5.26 The effect of declining water quality on the ecosystem[70]

Changes in water quality affect the biodiversity of reef systems. Higher concentrations of pollutants such as suspended sediments, nitrogen and phosphorus, indicated by higher chlorophyll concentrations and lower water clarity (measured as reduced secchi depth readings), result in more macroalgae and less hard coral diversity. Blue shading indicates 95% confidence intervals.

The increased concentrations of nitrogen in seawater after flood events induce rapid growth of planktonic algae, sometimes resulting in an algal bloom. If these conditions persist, such blooms can affect other species and the overall functioning of the ecosystem.[70] If an algal bloom coincides with a release of crown-of-thorns starfish larvae, it greatly increase the latter's chances of survival.

An algal bloom following a flood event, Mackay region February 2005. Excess nutrients in flood waters cause a population explosion of algae floating in the seawater.

Aggregations of 'marine snow' (Section 3.4.1) are another effect of increased nutrients leading to the smothering of small bottom-dwelling organisms including newly-settled coral larvae.[72]

Increased sediments cause damage to the ecosystem by reducing light penetration, smothering coral[73] and other small invertebrates and transporting nutrients and pesticides to the Great Barrier Reef (Section 3.4.2).[70] Herbicides can affect the health of plants in the marine environment (Section 2.2.1) and thus affect the levels of primary production in the ecosystem.

The timing of the exposure to pollutants may alter the severity of their effects. For example, corals are particularly vulnerable to contaminants during the time of spawning and larval settlement. Spawning generally occurs around October to November, prior to the initial wet season rainfall events and high runoff containing concentrated 'pulses' of pollutants. However, at the time of flood events corals may also be stressed by high water temperatures and low salinity.

A decline in inshore habitats will have economic and social implications for coastal communities.

Some pollutants such as heavy metals can persist for decades in the marine environment. They are known to accumulate in species that have high fat contents (such as whales, dolphins)[74], species which are higher in the food web[74] and in species which are long-lived.[49 75] For example, some dugongs on the Great Barrier Reef have been found with elevated levels of arsenic, chromium, mercury, manganese, nickel and/or lead in their tissues.[76] The effects of these heavy metals can include disruption to reproduction, impairment of the immune system, neurological disorders and the development of cancers[74] although these effects have not been specifically linked to declines in marine species on the Great Barrier Reef to date.

Added to the individual effects of nutrients, sediments and pesticides, there are cumulative effects that magnify the immediate impacts of catchment runoff. For example, crustose coralline algae are far more sensitive to damage by sedimentation when traces of the herbicide diuron are present.[70]

5.4.3 Implications of catchment runoff for regional communities

A decline in inshore habitats as a result of polluted water will have economic and social implications for industries and coastal communities that derive an income from these areas. Potential economic implications include declines in fish populations important for fishing, a decrease in recreational visitation, which has flow on effects to dependent local industries.

Enjoyment of the area is occasionally affected by algal blooms and increased turbidity which reduces underwater visibility. Although, to date, there has not been a decrease in visitor or tourist satisfaction to the Great Barrier Reef, this may occur if the quality of water entering the ecosystem continues to impact nearshore habitats.

5.5 Direct use

Direct use of the Great Barrier Reef Region includes commercial marine tourism, defence activities, fishing, ports and shipping, recreation, scientific research and traditional use of marine resources. The following analysis of direct use as a factor influencing the values of the Great Barrier Reef Region is based on the evidence presented in Chapters 2, 3 and 4.

5.5.1 Current state and trends of direct use

Commercial marine tourism The number of tourism visits to the Region has stabilised in the last decade with the overseas popularity of the Great Barrier Reef as a tourism destination strongly influenced by international events. Tourism activities are mainly focused on nature appreciation (especially of coral reef habitats) and any impacts are concentrated in a few popular, intensively managed areas. There is an increasing trend towards the achievement of high operating standards (environmental, economic and social) in addition to the mandatory management arrangements in place (Section 4.2).

Defence activities The Great Barrier Reef Region is an important training area for defence activities and is likely to remain so. All the defence activities are carefully managed and most have negligible impact (Section 4.3).

Fishing The Great Barrier Reef Region is an important resource for Queensland fisheries and it currently supplies about 14 000 tonnes of fisheries product each year. Mainly predators and particle feeders are targeted. The major commercial fisheries are net, trawl, line and pot. Recreational fishing is popular throughout the Region and is responsible for almost one-third of the retained catch by weight. Little is known about Indigenous and charter fishing. Global market trends are a major influence on commercial fishing patterns in the Great Barrier Reef, especially increasing demand for wild caught product and the world-wide expansion of aquaculture fisheries (Section 4.4).

Ports and shipping Ports and shipping activity is increasing in the Great Barrier Reef Region as the regional population grows and there is economic development of the hinterland (especially its mineral resources). Use of the Region for ports and shipping is not reliant on the Great Barrier Reef ecosystem and is mainly driven by global economic factors (Section 4.5).

Recreational use (not including fishing) It is estimated that, in 2008, about 14.6 million recreational visits were made to the Great Barrier Reef Marine Park by residents living within the Great Barrier Reef catchment. Recreational use is focused on coastal areas close to urban centres. Typically, people visit the Great Barrier Reef to enjoy swimming, fishing, boating and snorkelling. With the population of the Great Barrier Reef catchment predicted to increase from about 1 115 000 to 1 577 000 by 2026, recreational use of the Region is expected to continue to increase (Section 4.6).

Scientific research For many decades, the Great Barrier Reef ecosystem has been a major study area for tropical marine research, with research effort focused around the six research stations. The Region is likely to remain an important research area over the coming decades (Section 4.7).

Traditional use of marine resources For thousands of years, Traditional Owners of the Great Barrier Reef Region have visited and maintained connections with their traditional sea country, including traditional hunting and fishing, ceremonies, stories and looking after their country. Increasingly, Traditional Owners have the opportunity to formalise their aspirations for sea country management and to be involved in protection and management initiatives (Section 4.8).

5.5.2 Vulnerability of the ecosystem to direct use

The impacts of different uses of the Great Barrier Reef Region overlap and are concentrated inshore and next to developed areas. Direct use of the Region is likely to be having minor, if any, impact on many ecosystem processes, such as primary production, connectivity, nutrient cycling and sedimentation. Some uses may have positive benefits for the ecosystem through improving understanding about the ecosystem and contributing to management. However, there are some key groups of species and ecological processes that are affected by direct use.

Direct use is impacting some species groups and ecological processes including fish populations, predation and herbivory.

Fish (including sharks) More than 50 species of bony fish and sharks are targeted in fishing activities on the Great Barrier Reef, mainly predators. For these species, there are fewer fish in the regularly fished areas when compared to zones closed to fishing (Section 2.3.5) and some species are under pressure (including grey mackerel, garfish, snapper and several species of sharks) (Section 4.4.3).

Predation The ecological process of predation is being affected by direct use of the Region, especially as about half of the commercial fisheries take is of carnivores (Section 4.4.3). This may have flow on ecological effects on competition and the abundance of prey species (Section 3.4.5).

Some species of conservation concern continue to be impacted by direct use.

Herbivory Fish are the main herbivores on the Great Barrier Reef and, importantly, are not targeted in commercial or recreational fisheries (Section 4.4.3). However, two of the largest herbivores in the Great Barrier Reef ecosystem, dugongs and green turtles, were previously extensively harvested within the Great Barrier Reef Region, severely reducing their populations. Today, direct use of the Region is still contributing to the cumulative impacts on these populations (e.g. through bycatch in fishing gear, poaching, boat strikes, ingestion of marine debris) (Sections 2.3.6 and 2.3.8).

Particle feeding Particle feeders play a vital role in recycling nutrients from dead plants and animals. Many particle feeders, including prawns, scallops, crabs, lobsters and sea cucumbers are harvested in the Great Barrier Reef Region, historically at very high levels. Most populations are in good condition . However populations of some species (for example the black teatfish) do not appear to have recovered from this harvesting pressure (Section 3.4.2).

Coral reef habitats The extensive coral reef habitats of the Great Barrier Reef are the basis of much of the direct use of the Region, both extractive and non-extractive. Visiting and exploring coral reefs can result in damage to the coral substrate through anchoring, snorkelling and diving. The severity of these impacts is much reduced through reef protection infrastructure (such as moorings and markers) and the adoption of best practices. The broad scale and cumulative ecosystem effects of fishing on coral reefs are little studied (Section 4.4.3).

Direct use directly contributes to the economic value of the Great Barrier Reef, mainly derived from its natural resources.

Lagoon floor habitats The impact of trawling on the lagoon floor habitat is likely to be low because the areas now trawled are generally muddy, silty or sandy, are regularly disturbed naturally and the overall area in which trawling can occur has been reduced. Historically, damage to sensitive lagoon communities may have occurred as a result of trawling (Section 4.4.3).

Outbreaks of pests and introduced species While they are to some extent natural, there is evidence that outbreaks of crown-of-thorns starfish may be partially linked to reductions in predator populations. The number of reefs where outbreaks occur is markedly lower in zones closed to fishing (Section 3.4.5). The numbers of crown-of-thorns starfish are controlled by tourism operators at some high use tourism sites (Section 3.5.2). There is a risk that new species will be introduced to the Great Barrier Reef Region by fouling on vessels and discharge of ballast water, especially vessels from overseas (Section 4.6.3).

5.5.3 Implications of direct use for regional communities

Direct use of the Great Barrier Reef Region is a major part of regional communities. It is a significant source of employment and contributes to their overall economic well being (Section 4.1). Any future declines in the health of the Great Barrier Reef ecosystem could be expected to have serious economic implications for local communities as almost all the Region's economic benefit is derived from its natural resources, either through extraction of those resources or through tourism and recreation focused on the natural environment.

Direct use of the Great Barrier Reef Region provides social benefit to local communities and beyond, with millions of people visiting and enjoying the Great Barrier Reef each year (Sections 4.2.1 and 4.6.1). The predicted increase in recreational use of the Region may result in more conflicts of use and a loss of social amenity, but there is no evidence of this to date (Section 4.6.2).

The Region is of major importance to Traditional Owners and traditional use of and caring for their sea country reinforces Traditional Owner culture, protocols and connections to the Great Barrier Reef (Section 4.8.2).

5.6 Assessment summary – Factors influencing the Reef's values

Section 54(3)(g) of the *Great Barrier Reef Marine Park Act 1975* requires '*…an assessment of the factors influencing the current and projected future environmental, economic and social values…*' of the Great Barrier Reef Region. The assessment is based on three assessment criteria:

- impacts on environmental values
- impacts on economic values
- impacts on social values.

5.6.1 Impacts on environmental values

Assessment component	Summary	Assessment Grade: Very low impact	Low impact	High impact	Very high impact
Climate change	Almost all Great Barrier Reef species will be affected by climate change, some seriously. Coral reef habitats and seabirds are particularly vulnerable.				○
Coastal development	Increasing coastal development is resulting in the loss of both coastal habitats that support the Great Barrier Reef and connectivity between habitats.			○	
Catchment runoff	Increased concentrations of suspended sediments and agricultural chemicals are having significant effects inshore close to agricultural areas. Much continues to be done to improve water quality entering the Great Barrier Reef but it will be decades before the benefits are seen.			○	
Direct use	Direct use is impacting some species groups and ecological processes including fish populations, predation and herbivory. Some species of conservation concern continue to be impacted.		○		
Impact on environmental values	Climate change, particularly rising sea temperatures and ocean acidification, has already affected the Great Barrier Reef ecosystem and over the next 50 years it is likely to significantly affect most components of the ecosystem. The Great Barrier Reef, especially much of its inshore area, is being affected by increased nutrients, sediments and other pollutants in catchment runoff, mainly from diffuse agricultural sources, despite recent advances in agricultural practices. Coastal development is contributing to the modification and loss of coastal habitats that support the Great Barrier Reef. As the coastal population continues to grow there will be increasing use of the Great Barrier Reef and therefore the potential for further damage. Direct use of the Region is impacting on some environmental values.			○	

GRADING STATEMENTS

- **Very low impact** - Few or no impacts have been observed and accepted predictions indicate that future impacts on the Region's environmental values are likely to be minor.
- **Low impact** - Some minor impacts have already been observed and there is concern that, based on accepted predictions, there will be significant but localised impacts on the Region's environmental values.
- **High impact** - Current and predicted future impacts are likely to significantly affect the Region's environmental values. Concern about serious ecosystem effects within next 20-50 years.
- **Very high impact** - Current and predicted future impacts are likely to irreversibly destroy much of the Region's environmental values. Widespread and serious ecosystem effects likely within next 10-20 years.

5.6.2 Impacts on economic values

Assessment component	Summary	Assessment Grade: Very low impact	Low impact	High impact	Very high impact
Climate change	Climate related changes to the ecosystem are expected to seriously affect Reef-based industries and communities.			○	
Coastal development	An increasing coastal population is likely to increase the economic worth of recreational activities and Reef-dependent industries.		○		

Assessment component	Summary	Very low impact	Low impact	High impact	Very high impact
Catchment runoff	The impact of catchment runoff on inshore areas is expected to continue to affect the economic value of associated Reef-based industries.			○	
Direct use	Direct use directly contributes to the economic value of the Great Barrier Reef, mainly derived from its natural resources.	○			
Impact on economic values	Changes to the Great Barrier Reef ecosystem are likely to have serious economic implications for reef-dependent industries, such as tourism and fishing, and for adjacent communities. Perceptions about the health of the ecosystem also affect its attractiveness for tourism and recreation and, thus, its marketability. An increasing coastal population is likely to increase the economic value of Reef-based activities. The economic benefits of direct use will be affected by the impacts of external factors.			○	

GRADING STATEMENTS

Very low impact - Few or no impacts have been observed and accepted predictions indicate that future impacts on the Region's economic values are likely to be minor.

Low impact - Some minor impacts have already been observed and there is concern that, based on accepted predictions, there will be significant but localised impacts on the Region's economic values.

High impact - Current and predicted future impacts are likely to significantly affect the Region's economic values. Concern about serious effects on the Region's economic values within next 20-50 years.

Very high impact - Current and predicted future impacts are likely to irreversibly destroy much of the Region's economic values. Widespread and serious effects on the Region's economic values likely within next 10-20 years.

5.6.3 Impacts on social values

Assessment component	Summary	Very low impact	Low impact	High impact	Very high impact
Climate change	Climate-related changes to the ecosystem could affect patterns of use of the Great Barrier Reef and visitor satisfaction.			○	
Coastal development	Increasing coastal population is resulting in greater use of the Great Barrier Reef (this has not yet affected visitor satisfaction).		○		
Catchment runoff	A decline in inshore habitats will have social implications for coastal communities.		○		
Direct use	Direct use of the Region provides strong social benefits to regional communities and Traditional Owners. Future increasing use may diminish these benefits.		○		
Impact on social values	An increasing coastal population is likely to increase recreational use of the Region and change people's experiences of the Great Barrier Reef with increased congestion at popular recreation locations and competition for preferred sites. A decline in inshore habitats as a result of polluted water will have social implications for dependent industries and coastal communities. Traditional Owners are concerned about rising temperatures altering the seasonality and availability of marine resources as well as the potential loss of totemic species.		○		

GRADING STATEMENTS

Very low impact - Few or no impacts have been observed and accepted predictions indicate that future impacts on the Region's social values are likely to be minor.

Low impact - Some minor impacts have already been observed and there is concern that, based on accepted predictions, there will be significant but localised impacts on the Region's social values.

High impact - Current and predicted future impacts are likely to significantly affect the Region's social values. Concern about serious effects on the Region's social values within next 20-50 years.

Very high impact - Current and predicted future impacts are likely to irreversibly destroy much of the Region's social value. Widespread and serious effects on the Region's social values are likely within next 10-20 years.

5.6.4 Overall summary of factors influencing the Reef's values

Factors external to the Great Barrier Reef itself are playing an increasing role in determining its condition. Impacts from climate change have already been witnessed and all parts of the ecosystem are vulnerable to its increasing effects with coral reef habitats the most vulnerable. Coastal development, primarily driven by mining, industry and population growth, is still significantly affecting coastal habitats that support the Great Barrier Reef and the water quality of the Great Barrier Reef. Despite improvements in local land management, the quality of catchment runoff entering the Great Barrier Reef continues to cause deterioration in the water quality in the Great Barrier Reef Region.

Currently, changes in the use made of the Great Barrier Reef Region are mainly driven by external factors such as global economic conditions plus regional economic development and population growth. As many uses of the Region are based on the resources of the Great Barrier Reef ecosystem, the health of that ecosystem may become an increasingly important determinant of use.

Many of the threats from both the external factors and those from direct use within the Great Barrier Reef are combining to cause serious impacts on the ecosystem. All these factors are significant to the ecosystem's future functioning and resilience.

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EXISTING PROTECTION AND MANAGEMENT

CHAPTER SIX

"A special statutory authority should be established responsible to the appropriate Parliament for ecological protection and the control of research and development within the Great Barrier Reef Province."

Royal Commission into exploratory and production drilling for petroleum in the area of the Great Barrier Reef, 1974

'an assessment of the existing measures to protect and manage the ecosystem …' within the Great Barrier Reef Region, Section 54(3)(f) of the *Great Barrier Reef Marine Park Act 1975*

6 EXISTING PROTECTION AND MANAGEMENT

6.1 Background

How effectively the Great Barrier Reef is protected and managed strongly influences the resilience of the ecosystem. Many government agencies, stakeholders and community members contribute to protection and management of the Great Barrier Reef, both on the water and in the catchment. A broad assessment of the effectiveness of the management activities currently undertaken by all these contributors is an important component in determining the major risks that remain for the Great Barrier Reef and predicting its outlook.

6.1.1 Roles and responsibilities

Protection and management within the Region Both the Australian and Queensland Governments have direct legislative responsibilities within the Great Barrier Reef Region (figure 6.1).

The *Great Barrier Reef Marine Park Act 1975* establishes a Great Barrier Reef Marine Park Authority and governs its operations. The Great Barrier Reef Marine Park Authority manages the Great Barrier Reef Marine Park (see Map 1). This Commonwealth marine protected area is complemented by the Queensland Great Barrier Reef Coast Marine Park in adjacent Queensland waters. The main events in management of the Great Barrier Reef since the establishment of the Great Barrier Reef Marine Park Authority are set out in figure 6.2.

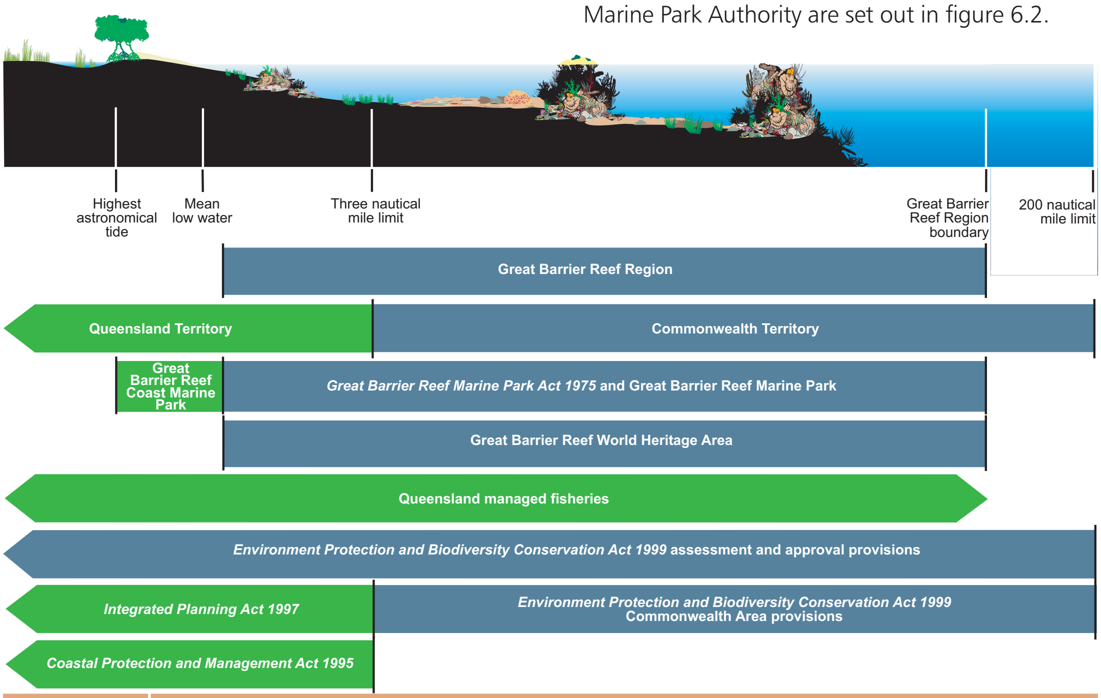


Figure 6.1 Jurisdictional boundaries for the Great Barrier Reef Region

The Great Barrier Reef encompasses both Commonwealth and Queensland jurisdiction. Joint marine parks management ensures integrated field management of both the Great Barrier Reef Marine Park and the adjacent Great Barrier Reef Coast Marine Park. Fisheries management, both within the Region and beyond, is a Queensland Government responsibility. The assessment and approval provisions of the *Environment Protection and Biodiversity Conservation Act 1999* apply throughout the Region, its Commonwealth Area provisions apply only in Commonwealth Territory. (Adapted from *Review of the Great Barrier Reef Marine Park Act 1975*[1])

1975 The *Great Barrier Reef Marine Park Act 1975* came into force.

1976 Inaugural meeting of the Great Barrier Reef Marine Park Authority.

1979 The Capricornia Section of the Great Barrier Reef Marine Park proclaimed. Prime Minister Malcolm Fraser and Premier of Queensland Joh Bjelke-Petersen signed the 'Emerald Agreement' setting out management arrangements for the Great Barrier Reef Marine Park.

1981 The *Capricornia Section Zoning Plan* came into operation. Cairns and Cormorant Pass Sections of the Great Barrier Reef Marine Park proclaimed. Great Barrier Reef inscribed on World Heritage List.

1983 Far Northern, Central, Townsville, Southern and Inshore Southern Sections of the Great Barrier Reef Marine Park proclaimed. *Great Barrier Reef Marine Park Regulations* came into effect. Zoning plans for Cairns and Cormorant Pass Sections came into operation.

1985 *Central Section Zoning Plan* came into operation.

1986 *Far Northern Section Zoning Plan* came into operation.

1987 Mackay/Capricorn Section proclaimed.

1988 *Mackay/Capricorn Section Zoning Plan* came into operation.

1990 International Maritime Organisation declared the Great Barrier Reef as the world's first marine Particularly Sensitive Sea Area.

1992 Second *Cairns Section Zoning Plan* came into operation.

1993 Environmental Management Charge introduced. Cooperative Research Centre for Ecologically Sustainable Development of the Great Barrier Reef commenced.

1994 First Native Title claim lodged for an area covering part of the Great Barrier Reef Marine Park. Launch and publication of *Great Barrier Reef: keeping it great; a 25 year strategic plan for the Great Barrier Reef World Heritage Area, 1994–2015.* Regional Marine Resources Advisory Committees established.

1998 Gumoo Woojabuddee Section proclaimed. *Cairns Area Plan of Management* and *Whitsundays Plan of Management* gazetted.

1999 The *Environment Protection and Biodiversity Conservation Act 1999* proclaimed. Local Marine Advisory Committees established in nine regions.

2000 Eighteen new coastal areas gazetted into the Great Barrier Reef Marine Park. Four Reef Advisory Committees established.

2001 Ten new coastal areas gazetted into the Great Barrier Reef Marine Park. The Australian Government's *Great Barrier Reef Catchment Water Quality Action Plan 2001* released.

2002 Second *Far Northern Section Zoning Plan* and *Gumoo Woojabuddee Section Zoning Plan* came into operation.

2003 The joint Australian and Queensland Government *Reef Water Quality Protection Plan 2003* comes into effect aimed at halting and reversing the decline in water quality in Great Barrier Reef waters.

2004 *Great Barrier Reef Marine Park Zoning Plan 2003* came into operation. Queensland matched the new zoning in virtually all adjoining State waters. *Hinchinbrook Plan of Management* gazetted. Great Barrier Reef Marine Park Authority issues first 15-year permit to a high standard tourism operator.

2006 Review of the *Great Barrier Reef Marine Park Act 1975* published. Reef and Rainforest Research Centre commenced.

2007 *Great Barrier Reef Marine Park Act 1975* amended including provisions for the development of the Great Barrier Reef Outlook Report.

2008 The Australian Government announces its Reef Rescue package providing $200 million over five years to support improved land and sea management practices.

Figure 6.2 Main events in management of the Great Barrier Reef

A joint management arrangement between the Australian and Queensland Governments ensures integrated field management of the two marine protected areas, plus protected areas on the islands within the Region. Since 1979, when the arrangements were agreed, a close working relationship has developed between the responsible government agencies, resulting in joint management on many issues within the protected areas. Many other Australian and Queensland Government agencies, industry groups, community groups and individuals also directly participate in protection and management of the Great Barrier Reef (table 6.1).

Goal of the Great Barrier Reef Marine Park Authority

To provide for the long-term protection, ecologically sustainable use, understanding and enjoyment of the Great Barrier Reef through the care and development of the Great Barrier Reef Marine Park.

Table 6.1	Major contributors to the protection and management of the Great Barrier Reef ecosystem

Many agencies, organisations and individuals contribute to the protection and management of the Great Barrier Reef ecosystem. All their management activities are broadly considered in this assessment.

Australian Government

Great Barrier Reef Marine Park Authority

Responsible for the planning and management of the Great Barrier Reef Marine Park.

Department of the Environment, Water, Heritage and the Arts

Develops and implements national policies, programs and legislation to protect and conserve Australia's natural environment and heritage.

Department of Climate Change

Responsible for leading the development and coordination of Australia's climate change policies and programs.

Australian Customs Service

Enforces a range of Commonwealth laws at sea and at various international entry points, including ports. Coastwatch provides aerial surveillance of Australian coastal waters.

Australian Maritime Safety Authority

Responsible for managing shipping activities throughout the Great Barrier Reef Region. Coordinates emergency responses to marine emergencies and marine pollution (for example oil spills).

Australian Quarantine Inspection Service

Responsible for quarantine inspection services for all vessels entering Australian waters.

Department of Agriculture, Fisheries and Forestry

Develops and implement policies and programs that ensure Australia's agricultural, fisheries, food and forestry industries remain competitive, profitable and sustainable.

Department of Defence

Responsible for all defence activities within the Great Barrier Reef Region, including the management of designated defence training areas.

Department of Resources, Energy and Tourism

Develops and delivers policies to increase Australia's international competitiveness in relation to resources, energy and tourism, consistent with the principles of environmental responsibility and sustainable development.

Queensland Government

Department of Environment and Resource Management (formerly the Environmental Protection Agency and the Department of Natural Resources and Water)

Responsible for the management of Queensland's natural resources and environment, including water, salinity, vegetation management, Native Title, threatened species, resource security and sustainable development. Lead agency to the Queensland Government for environmental management matters including the assessment and approval of works in intertidal areas, internal waters and the Great Barrier Reef catchment. Within the Department, **Queensland Parks and Wildlife Service** is responsible for field management in the Great Barrier Reef Coast Marine Park plus island and mainland National Parks. Queensland Parks and Wildlife Service is also the primary agency responsible for field management in the Great Barrier Reef Marine Park.

Department of Employment, Economic Development and Innovation (includes the former Department of Primary Industries and Fisheries)

Responsible for management of and research on fisheries and fisheries habitat in the Great Barrier Reef Region. The **Queensland Boating and Fisheries Patrol** is responsible for enforcement of fisheries regulations (including Dugong Protection Areas) and Marine Parks and transport legislation. The Department also provides a range of services to industries, business, research organisations, and government bodies to grow regional economies and strengthen industries.

Department of the Premier and Cabinet

Provides overall coordination and direction for Queensland Government involvement in Great Barrier Reef matters. Within the Department, the Reef Secretariat provides support for the Reef Water Quality Protection Plan.

Department of Infrastructure and Planning

Ensures essential planning and infrastructure are developed and delivered. This includes the development of regional plans along the Great Barrier Reef coast.

Department of Transport and Main Roads

Responsible for providing policy and strategic advice relating to Queensland's ports system. Within the Department, **Maritime Safety Queensland** is responsible for licencing, registration and the safe navigation of vessels. It is the lead response agency for oil and chemical spills.

Queensland Water Police

Enforces Marine Parks legislation and investigates crimes on the water.

Table 6.1 (continued)

Other Partners

Local Government
Responsible for local management within the Great Barrier Reef catchment.

Natural Resource Management Bodies
Coordinate natural resource management activities in the Great Barrier Reef catchment.

Research Institutions
Provide improved knowledge about the Great Barrier Reef and advice on its implications for management

Industry Groups
Organise and participate in programs that contribute to protection and management (for example Association of Marine Park Tourism Operators, Queensland Seafood Industry Association, Queensland Cane Growers Association and Growcom).

Community Groups
Organise and participate in community activities that help understand and protect the Great Barrier Reef.

Environmental Non-Government Organisations
Raise public awareness about the state of the Great Barrier Reef and advocate for its increased conservation and protection.

Schools
Educate and engage students in marine activities and conservation.

Recollections about community involvement

Joe Linton is a canefarmer in the Burdekin who has owned many boats and fished all his life. He is member of the **Townsville Local Marine Advisory Committee** (LMAC):

"If you stick in your own little corner you'll always come out fighting. If you're pro development or pro fishing or pro conservation it doesn't matter what angle you're coming from, you'll always be biased to that sort of approach. But what I've found by being involved in groups like the LMAC, it gives you a real opportunity to be able to sit across the table and talk with and argue on some occasions, but get an opportunity to get the message from the other side in an open manner so it's not confrontationist."

Marine Parks field management is a joint operation by Australian and Queensland Government agencies.

The Great Barrier Reef Marine Park Authority receives advice on the protection and management of the Great Barrier Reef Marine Park from 11 Local Marine Advisory Committees and four issues-based Reef Advisory Committees and places a strong emphasis on community engagement, consultation and participation. The Queensland Government also has a range of advisory and engagement mechanisms that include consideration of Great Barrier Reef matters, including fisheries Management Advisory Committees and the State-wide Tourism Industry Forum.

Many agencies and groups contribute to protection and management of the Great Barrier Reef.

Protection and management outside the Region Many of the threats to the Great Barrier Reef ecosystem are the result of actions beyond the boundaries of the Great Barrier Reef Region (such as coastal development and catchment land use practices). There is a range of Australian, Queensland and local Government agencies that have regulatory responsibilities for these matters.

In addition, natural resource management bodies, industry groups, community groups and individuals are involved in addressing these threats and therefore improving outcomes for the Great Barrier Reef Region. The Great Barrier Reef Marine Park Authority has no direct management responsibilities beyond the boundaries of the Great Barrier Reef Region.

6.1.2 Focus of management

Activities to protect and manage the Great Barrier Reef are focused on 12 broad management topics:

- biodiversity protection
- climate change
- coastal development
- commercial marine tourism
- defence
- fishing (commercial and recreational)
- heritage
- ports and shipping
- recreation (not including fishing)
- scientific research
- traditional use of marine resources
- water quality.

Some of these management topics are localised issues that affect only a small proportion of the Great Barrier Reef Region (for example defence) while others have implications across all or most of the Great Barrier Reef Region (for example climate change, biodiversity and heritage).

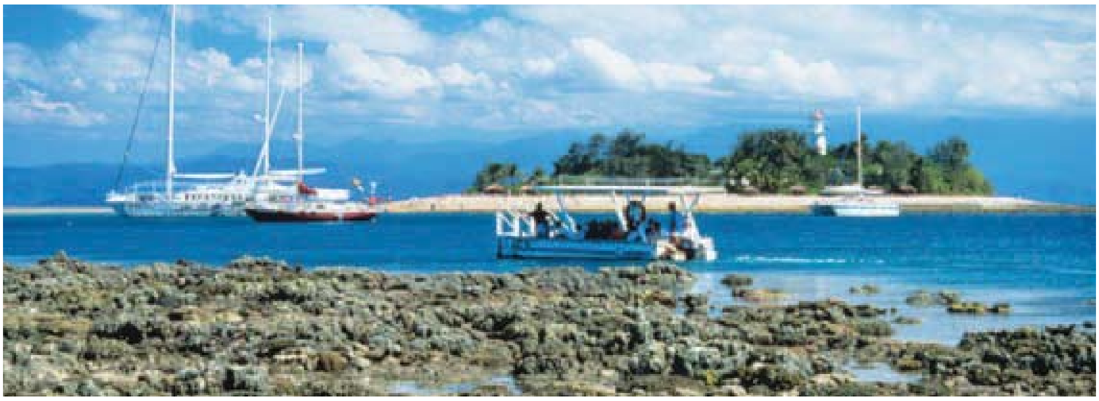
The required assessment of the effectiveness of protection and management measures is structured around these management topics.

6.1.3 Management tools

In addressing each of the management topics, a range of management tools are employed, often both inside the Great Barrier Reef Region and beyond its boundaries. These include legislation, zoning plans, permits and licences, management plans, site management, policy, research, partnerships and best practices, education and community awareness, plus compliance and enforcement (table 6.2). For example, commercial marine tourism is managed through zoning plans, permits, plans of management, site management, policy, partnerships, best practices, education and compliance.

Actions to protect and manage the Great Barrier Reef ecosystem are undertaken both within the Great Barrier Reef Region and well beyond its boundaries. The management of some of the topics is principally confined to actions within the Great Barrier Reef Region (such as commercial marine tourism, defence and scientific research), while other topics require actions outside and sometimes well beyond the Great Barrier Reef (such as climate change, coastal development and water quality).

In addition, any one management tool may be employed to address a number of topics (table 6.3). For example, legislation such as the *Environment Protection and Biodiversity Conservation Act 1999* governs biodiversity protection, coastal development applications and fisheries export approvals. Some measures are specific to an area (e.g. the *Whitsundays Plan of Management*) or an activity (e.g. the *Fisheries (East Coast Trawl) Management Plan 1999)*.



The full range of management tools are employed at popular and historically significant locations such as Low Isles, offshore Port Douglas.

Table 6.2 Examples of management tools employed to protect and manage the Great Barrier Reef ecosystem

Legislation	The *Great Barrier Reef Marine Park Act 1975* and Regulations govern the protection and management of the Great Barrier Reef Marine Park. Provides for the Zoning Plan and Plans of Management. Matched in areas of Queensland jurisdiction by the *Marine Parks Act 2004*. Other Commonwealth and Queensland legislation also applies in the Region, for example the *Environment Protection and Biodiversity Conservation Act 1999*.
Zoning plans	Provides spatial control of use (predominantly extractive activities) and, to a lesser extent, access within the Great Barrier Reef Marine Park. Establishes the need for permits for some uses in the Marine Park, such as tourism and research. Complementary arrangements in adjacent areas under Queensland jurisdiction.
Permits and licences	Facilitate opportunities for use of the Great Barrier Reef. Marine Parks permits are issued mainly for marine tourism, research, harvest fisheries and major projects (e.g. marinas) and include detailed environmental impact assessment. Matched in adjacent areas of Queensland jurisdiction, generally providing a joint permit. Fisheries licences are issued by the Queensland Government.
Management plans	Set out specific arrangements for areas, species, ecological communities or activities. Some are legally binding, such as the Great Barrier Reef Marine Park Authority Plans of Management, others are policy based. Complement zoning and permitting arrangements.
Site management	On ground management arrangements for an individual site, including moorings, no anchoring areas and transit lanes.
Policy	Specific arrangements that guide decision makers and the public on the practical application of the legislation, for example in relation to the management of moorings or the take of protected species.
Research	Undertaken by a number of research institutions and community groups to better inform decisions on protection and management of the Great Barrier Reef.
Partnerships and best practices	Voluntary arrangements with stakeholders and the community that provide the opportunity for contributions to protection and management, for example through the adoption of best environmental practices or codes of conduct via Reef Guardian Councils and eco-certification.
Education and community awareness	Programs such as the Reef Guardian Schools Program and Reef HQ Aquarium that inform and motivate members of the community about protection and management of the Great Barrier Reef.
Compliance	Activities that encourage adherence with legal requirements, both through education and enforcement.

Table 6.3 Management tools used in addressing the broad management topics of the Great Barrier Reef

Management tools	Biodiversity protection	Climate change	Coastal development	Commercial marine tourism	Defence	Fishing	Heritage	Ports and shipping	Recreation (not including fishing)	Scientific research	Traditional use of marine resources	Water quality
Legislation	●		●	●	●	●	●	●	●	●	●	●
Zoning plans	●			●	●	●	●	●	●	●	●	
Permits and licences	●		●	●		●	●	●		●	●	●
Management plans – legally binding	●		●	●		●	●		●	●	●	
Management plans – policy	●	●	●	●	●	●	●	●	●	●	●	●
Site management	●		●	●	●		●	●	●	●		●
Policy	●	●	●	●	●	●	●	●		●	●	●
Research	●	●		●		●	●	●	●		●	●
Partnerships and best practices	●	●	●	●	●	●	●	●	●	●	●	●
Education and community awareness	●	●	●	●	●	●	●	●	●	●	●	●
Compliance	●		●	●		●	●	●	●	●	●	●

Great Barrier Reef Marine Park Zoning Plan 2003

The *Great Barrier Reef Marine Park Zoning Plan 2003*, which came into effect on 1 July 2004, is the primary management tool for the protection of the Great Barrier Reef ecosystem. It protects biodiversity by regulating some aspects of use in the Great Barrier Reef Marine Park, particularly fishing and shipping. It also separates potentially conflicting uses and specifies the uses for which a permit is required, for example marine tourism and research. The Queensland Government has developed a complementary zoning plan for the adjacent Great Barrier Reef Coast Marine Park.

By the mid 1990s it was recognised that levels of protection were inadequate to protect the range of biodiversity within the Great Barrier Reef – an important requirement for maintaining the resilience of the ecosystem. Many habitats (for example, inshore marine habitats or deep offshore waters) were, at that time, poorly represented in highly protected (no-take) areas (figure 6.3-inset). Through the Representative Areas Program, 70 major habitat types were identified in the Great Barrier Reef Region and a new Zoning Plan developed (figure 6.3), based on protecting 'representative' examples of each habitat type within a network of highly protected areas. An important aim was to maximise the benefits and minimise the negative impacts of the rezoning on the existing users of the Marine Park. As a result of this program, the area of highly protected zones in the Great Barrier Reef Marine Park increased from 4.5 per cent to 33 per cent (table 6.4). A minimum of 20 per cent of each habitat type is protected, increasing to a higher percentage in some habitats. Equally important, the no-take zoning network is complemented by other zone types and management arrangements, aimed at the comprehensive protection of plants, animals and habitats while providing opportunities for sustainable use.

The community was engaged extensively throughout the development of the Zoning Plan, with two phases of formal community participation. A record number of submissions were received – over 10 000 written submissions in the first phase and over 21 500 in the second. Since the zoning has come into effect, more than one million free Zoning Maps have been distributed by the Great Barrier Reef Marine Park Authority and 200 Community Access Points - bait and tackle shops, boating suppliers and government agencies.

The effects of the rezoning are being monitored, and positive changes to the ecosystem are being recorded, particularly in the recovery of fish populations (see Sections 2.2.3, 2.3.5, 3.4.5, 7.2.2, 7.2.3, 7.2.4).

Table 6.4 | Changes in zone area following rezoning in 2004

Zone	Area in each zone: Before rezoning	Area in each zone: Current
Preservation Zone (pink)	0.1%	0.2%
Marine National Park (green)	4.6%	33.3%
Scientific Research (orange)	0.01%	0.05%
Buffer Zone (olive)	0.1%	2.9%
Conservation Park (yellow)	0.6%	1.5%
Habitat Protection (blue)	15.2%	28.2%
General Use (light blue)	77.9%	33.8%

Figure 6.3 | inset

Figure 6.3 **Zoning of the Great Barrier Reef Marine Park**

Prior to 1 July 2004, only 4.5 per cent of the Great Barrier Reef Marine Park was within highly protected zones and many of these were focused on coral reef areas (see inset, previous page). After 1 July 2004, more than 33 per cent was within highly protected zones (Marine National Park, Preservation). Each of the Marine Park zones has a specific objective (refer Figure 1.1).

6.1.4 Assessing protection and management measures

In order to ensure the independence of the assessment of existing measures to protect and manage the ecosystem the Great Barrier Reef Marine Park Authority commissioned two external assessors to undertake the assessment. These assessors have expertise in protected area management, monitoring and evaluation, public policy and governance. The Great Barrier Reef Marine Park Authority accepted their report[2], and it forms the basis of Sections 6.2 and 6.3 of this chapter.

Scope The assessment includes all activities that contribute to protection and management of the Great Barrier Reef. Management actions that take place both inside and outside the Great Barrier Reef Region are examined to the extent that they influence the protection and management of the Great Barrier Reef ecosystem. The assessment therefore considers the actions of a range of contributors to protection and management, not just activities of the Great Barrier Reef Marine Park Authority.

Figure 6.4 The management cycle

Effective management is a closed loop where issues are considered, plans are made, resources are expended, proper processes are followed and products and services are delivered, all leading to outcomes that address the issues. (Adapted from Hockings et al. 2006[3])

This assessment is of the effectiveness of existing management activities and arrangements. The *Great Barrier Reef Marine Park Act 1975* does not provide for the Outlook Report to make recommendations about future protection and management initiatives.

Assessment methodology The Terms of Reference for the external assessment included a requirement to follow the framework for evaluating management of protected areas developed by the International Union for the Conservation of Nature and Natural Resources (IUCN) World Commission on Protected Areas.[3] This framework is based on a management cycle in which management is continuously evaluated and refined (figure 6.4). The most effective management is achieved when all steps in the cycle are functioning well.

An assessment of each of the steps in this management cycle provides a complete picture of management effectiveness. For example, assessing only outcomes may indicate a particular objective has been achieved but leaves it unclear as to whether this was due to good luck or good management. Conversely, it may be hard to understand why desired outcomes were not achieved unless all management steps are examined.

Given the time constraints for this assessment, it did not examine individual management tools in detail. Rather, it was a high level overview of the 12 management topics.

Information used Detailed information on current management was collated by both Australian and Queensland Government agencies and provided to the assessors. The assessors were also provided with advice on management effectiveness from the Great Barrier Reef Marine Park Authority's Local Marine Advisory Committees and Reef Advisory Committees, plus the Outlook Forum. These groups had each considered management of the Great Barrier Reef ecosystem and provided an analysis of which aspects were working and which needed improvement.

6.2 Assessment of existing protection and management measures

The following assessment of existing measures to protect and manage the ecosystem within the Great Barrier Reef Region is an independent analysis by two external expert assessors.

The full report of the assessors[2] is available online at *www.gbrmpa.gov.au*.

This assessment of existing measures to protect and manage the ecosystem is structured around the IUCN management cycle and examines each of the 12 broad management topics as the key components of the existing measures to protect and manage the Great Barrier Reef. The assessment makes no recommendations for improvements, as this was outside its scope, but seeks to provide clear explanations for the grading judgements made. This emphasis in the text may, in some sections, appear to place undue focus on relatively minor negative attributes rather than on an overall positive result. However, the intent is simply to maximise the usefulness of the assessment for those considering management responses to the issues raised.

The assessment is based on documentation available and advice provided before the end of September 2008. Where practicable, information has been updated after this date, but this has not been comprehensive. The management topics were not weighted and the performance assessments need to be interpreted in the context of differences in scale and complexity (table 6.5).

Table 6.5 Scale and complexity of Great Barrier Reef management topics

		Complexity		
Management topic	**Scale**	**Social**	**Biophysical**	**Jurisdictional**
Biodiversity protection	Region-wide	minor	major	moderate
Climate change	Region-wide	major	major	major
Coastal development	Coastal catchment areas and mainly inshore waters	major	major	major
Commercial marine tourism	Region-wide but variable in intensity	major	moderate	moderate
Defence	Limited in area and duration	minor	minor	minor
Fishing	Region-wide but variable in intensity	major	major	moderate
Heritage	Region-wide	moderate	minor	moderate
Ports and shipping	Concentrated around ports and shipping lanes	moderate	moderate	moderate
Recreation (not including fishing)	Region-wide but variable in intensity	major	moderate	moderate
Scientific research	Region-wide but limited in intensity	minor	moderate	minor
Traditional use of marine resources	Region-wide but variable in intensity	major	moderate	moderate
Water quality	Great Barrier Reef catchment and mainly inshore waters	major	major	major

For each of the management topics, a series of questions were considered in relation to each stage of the management cycle (table 6.6) and qualitatively assessed on a four point rating scale. Details of the assessment process are available in the full report.[2]

Table 6.6 Considerations used to assess effectiveness for each management topic

Understanding of context

- Values in the Great Barrier Reef relevant to the topic are understood by managers.
- Local risks and threats (i.e. within and adjacent to the Great Barrier Reef) associated with the topic are understood by managers.
- Broader (including global) risks and threats relevant to the topic are understood by managers.
- Regional and national level influences relevant to the topic are understood by managers.
- International and global influences relevant to the topic are understood by managers.
- Stakeholders relevant to the topic are well-known by managers.

Planning

- There is a planning system in place that effectively addresses the topic.
- The planning system for the topic addresses the major risks/threats to the Great Barrier Reef's values.
- Actions for implementation regarding the topic are clearly identified within the plan.
- Clear, measurable and appropriate objectives for management of the topic have been documented.
- Main stakeholders and/or the local community are effectively engaged in planning to address the topic.
- Sufficient policy currently exists to effectively address the topic.
- There is consistency across jurisdictions when planning for the issue.

Financial, staffing and information inputs

- Current financial resources are adequate and prioritised to meet specific management objectives to address the topic.
- Current financial resources are secure (ongoing, or at least secure for the next three years) to address the topic.
- Current human resources within the managing organisations are adequate to meet specific management objectives to address the topic.
- Current human resources within the managing organisations are secure (ongoing, or at least secure for the next three years) to address the topic.
- The right skill sets and expertise are currently available to the managing organisations to address the topic.
- Necessary biophysical information is currently available to address the topic.
- Necessary socio-economic information is currently available to address the topic.
- Necessary traditional (Indigenous) knowledge is currently available to address the topic.
- There are additional sources of non-government input (e.g. volunteers) contributing to address the topic.

Management systems and processes

- Main stakeholders and/or industry(ies) are effectively engaged in the ongoing management of the topic.
- Local community is effectively engaged in the ongoing management of the topic.
- There is a sound governance system in place to address the topic.
- There is effective performance monitoring to gauge progress towards the objective(s).
- Appropriate training is available to the managing agencies to address the topic.
- Management of the topic is consistently implemented across the relevant jurisdictions.
- There are effective processes applied to resolve differing views and conflicts regarding the topic.
- Cumulative impacts of activities associated with the topic are appropriately considered.
- Best available biophysical research and/or monitoring information is applied appropriately to make relevant management decisions regarding the topic.
- Best available socio-economic research and/or monitoring information is applied appropriately to make relevant management decisions regarding the topic.
- Best available traditional (Indigenous) knowledge is applied appropriately to make relevant management decisions regarding the topic.
- Relevant national standards are identified and being met regarding the topic.
- Relevant international standards are identified and being met regarding the topic.

Delivery of outputs

- To date, the actual management programs (or activities) have progressed in accordance with the planned work program for the topic.

Table 6.6 (continued)

- Implementation of management documents and/or programs relevant to the topic have progressed in accordance with timeframes specified in those documents.
- Results of actual management programs or activities have achieved their stated management objectives.
- To date, products or services have been produced in accordance with the stated management objectives for the topic.
- The knowledge base for the topic within agencies has increased over the last three to five years.
- The knowledge base for the topic in the wider community has increased over the last three to five years.

Achievement of outcomes

- Relevant managing agencies are to date effectively addressing the topic and moving towards the attainment of the desired outcomes.
- Outputs relating to the topic are on track to ensure the values of the Great Barrier Reef are protected.
- Outputs for the topic are reducing the major risks and the threats to the Great Barrier Reef.
- Use of the Great Barrier Reef relating to the topic is demonstrably environmentally sustainable.
- Use of the Great Barrier Reef relating to the topic is demonstrably economically sustainable.
- Use of the Great Barrier Reef relating to the topic has demonstrably enhanced community understanding and/or enjoyment.
- Relevant managing agencies have developed effective partnerships with local communities and/or stakeholders to address the topic.

6.2.1. Biodiversity protection

Protection of the biodiversity of the Great Barrier Reef is the primary objective for much of the management action undertaken in the Great Barrier Reef and its catchment.

Many biodiversity protection measures, for example zoning plans, are making a difference, but there is no overarching framework to guide and coordinate management actions.

Management is undertaken using an array of measures, principally zoning plans, but also incorporating management plans, permit assessments, site management, education and best practices. A potentially complex and confusing management regime has been simplified through inter-governmental coordination, for example, the zoning plans. Depending on the jurisdiction that applies, the lead agency is either the Great Barrier Reef Marine Park Authority or the Queensland Department of Environment and Resource Management. The Department of the Environment, Water, Heritage and the Arts, the Australian Quarantine Inspection Service and the Queensland Department of Employment, Economic Development and Innovation also have some management responsibilities.

Threat abatement plans, recovery plans and specific on-the-water actions (for example Reef Protection Markers, Special Management Areas and Dugong Protection Areas) are in place to ensure that individual biodiversity issues are addressed. With regard to threatened species, such as dugongs and marine turtles, these plans and actions have had some effect as most populations have stabilised, but recovery has been weak indicating other threats remain.

On a Reef-wide scale, the *Great Barrier Reef Marine Park Zoning Plan 2003*, which came into effect in 2004, and is matched in the adjacent Great Barrier Reef Coast Marine Park, is the most significant action taken to enhance biodiversity protection. It has provided a robust framework and is already demonstrating positive results. However, the zoning provisions only address biodiversity protection at a broad level and, while some threats are addressed by other measures, major threats to biodiversity, such as climate change, coastal development and catchment runoff are not addressed by either the zoning provisions or individual biodiversity protection measures.

There is no one measure across the jurisdictions that spells out the overall objectives of the various biodiversity protection initiatives and performance monitoring is limited to a small number of target species, such as dugongs and some coral, fish and marine turtle species. In addition, there is little capacity to track either the resource allocations specifically targeting biodiversity objectives or the outputs and outcomes resulting from management actions. Major risks and threats to biodiversity protection are well documented and risk assessment and management procedures are in place for the major threats. However, there is no comprehensive documentation of risks to biodiversity values and mitigation measures for the entire Great Barrier Reef Region.

The Great Barrier Reef is an extensively studied biological region and many of the research projects undertaken or funded by the Region's major research bodies (principally the Australian Centre of Excellence for Coral Reef Studies, Australian Institute of Marine Science, James Cook University, University of Queensland and the Marine and Tropical Sciences Research Facility) are focused on improving protection of biodiversity. Gaps in knowledge, for example some specific plant and animal groups, habitats and ecosystems, are well recognised. Relevant Traditional Owner knowledge is often not available or accessible to managers.

Consideration of cumulative impacts, ecosystem resilience and connectivity issues is currently lacking or not reflected explicitly in most measures for biodiversity protection.

Key stakeholders in biodiversity protection have been identified and are generally well known to managers especially through Reef Advisory Committees, Local Marine Advisory Committees and other consultative mechanisms.

6.2.2 Climate change

Climate change is a global issue that could have catastrophic consequences for the Great Barrier Reef ecosystem. This assessment considers the topic of climate change in relation to any proactive and adaptive management measures undertaken specifically to protect and manage the Great Barrier Reef. The broader national and global initiatives to address climate change are not considered.

The Australian Department of Climate Change has lead responsibility for climate change policy development and is complemented within Queensland jurisdiction by the Office for Climate Change in the Queensland Department of Environment and Resource Management. The Department of the Environment, Water, Heritage and the Arts and the Great Barrier Reef Marine Park Authority also play significant roles. The management agencies responsible for the Great Barrier Reef are contributing significantly to the development of international best practice for responding to climate change in relation to coral reef ecosystems.

The broad threats to the Great Barrier Reef from climate change are understood and management emphasis is on adaptation and improving resilience to change.

A comprehensive vulnerability assessment for the Great Barrier Reef produced by the Great Barrier Reef Marine Park Authority in 2007 provides good contextual information for the management of climate change implications.[4] Key threats such as increasing sea temperatures, ocean acidification, sea level rise and increased severity of storm events are recognised.

Significant resources are being allocated at all levels of government and industry to assess threats and develop adaptation plans, and measures are in place for many aspects relating to the Great Barrier Reef. For example, implementation of the $8.9 million *Great Barrier Reef Climate Change Action Plan* is aimed at understanding the vulnerability of the Great Barrier Reef and helping to build resilience to climate change in the ecosystem, and the communities and industries that depend on it. For all these plans and measures, the challenge remains to translate them into specific policies and measurable on-ground actions. For some, pilot programs are being undertaken at demonstration sites to capture lessons which can be applied elsewhere. Relevant staff training is proceeding in parallel.

Gaps in information about biophysical effects and the flow-on socio-economic implications are recognised. Efforts are underway, working with Traditional Owners, to gather available traditional knowledge and ensure it is appropriately managed and applied to the issue of climate change. There is also successful community engagement on climate change through programs such as Bleachwatch, Reef Guardian Schools and tourism industry input including via eco-certification. Partnerships to reduce carbon footprints and increase stewardship are being developed with the fishing industry.

6.2.3 Coastal development

Management of coastal development is mainly through the application, principally at the local government level, of Queensland Government legislation and policy, including dedicated coastal protection legislation in the *Coastal Protection and Management Act 1995*. In addition, the provisions of the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* and, in some cases, the *Great Barrier Reef Marine Park Act 1975* serve to address the environmental impacts of some coastal works.

The lack of integrated regional and local plans for the coastal catchments indicates a significant shortcoming of the planning system. Since 2004, the Queensland Government has begun a process of rolling out statutory regional plans in place of existing non-statutory plans. The *Far North Queensland Draft Regional Plan*, due for release in early 2009, does pay particular attention to the significance of the Great Barrier Reef and the need to address threats to the ecosystem from coastal development activities. The population of the Great Barrier Reef catchment is increasing rapidly without full consideration of implications for the Great Barrier Reef ecosystem and the continuing degradation of coastal environments along much of the coast. The Queensland Government's 2007 commitment to an accelerated regional planning program provides a mechanism for these issues to be addressed. A reasonable knowledge of the general impacts and issues arising from coastal development is evident in many documents related to Great Barrier Reef management. However, there is a lack of a consistent set of goals and objectives to guide coastal development across all the agencies and sectors involved.

A lack of integrated planning, resources and enforcement in managing coastal development is compromising protection of the Great Barrier Reef.

The *State Coastal Management Plan - Queensland's Coastal Policy*, which came into effect in 2002, does not reflect the international significance of the Great Barrier Reef. The current state-wide and regional plans include policy provisions to address coastal use and development, water quality, scenic amenity and nature conservation while recognising the need to allow for development such as marine infrastructure. These plans generally recognise threats and risks relevant to the Great Barrier Reef, such as loss of coastal wetlands and modification of floodplains, but the risks are often not directly addressed or mitigated. Findings of a recent statutory review of the *State Coastal Management Plan* have indicated the need for revising the existing policy to ensure policy currency and remove duplication with more recent initiatives. The revision will also aim to better coordinate coastal planning under the *Integrated Planning Act 1997*.

The planning system, particularly the *Integrated Planning Act 1997*, theoretically provides a framework within which the major threats and risks to Great Barrier Reef values can be addressed, but without the relevant regional plans, there is little guidance for local planning decisions. There is also limited capacity in some local government authorities to deal with the complex issues involved in coastal development. Pressure from stakeholders and high levels of staff turnover are significant issues in some areas. In addition, engagement of stakeholders through planning processes is generally not comprehensive and balancing government priorities, community concerns and technical input is a significant challenge at the local level.

Some Queensland Government agencies have sought to address the lack of resources for planning and implementation by providing dedicated support for local government authorities.

Compliance monitoring and enforcement is limited, further constraining prospects for addressing the cumulative impacts of coastal development decisions.

6.2.4 Commercial marine tourism

Management of tourism in the Great Barrier Reef is focused on delivering high quality sustainable tourism experiences which have significant economic value to the local communities and to Australia. The environmental impacts of tourism, including social impacts such as crowding are minimised. This approach is given effect across the Commonwealth and Queensland jurisdictions through zoning plans, regulations, permits, management plans and a range of best practice and partnership initiatives.

Sound governance, industry partnerships and management processes are in place to manage marine-based tourism and the Great Barrier Reef is widely recognised as a world leader in this area. Plans and permitting arrangements are systematic and professionally implemented, and a robust array of policies, position statements and guidelines have been developed targeting sustainable tourism. Joint permitting and assessment processes between the Great Barrier Reef Marine Park Authority and the Department of Environment and Resource Management support consistency across jurisdictions. However, there is no overarching Reef-wide strategy to assist consistency across all jurisdictions.

Coordinated and professional management of tourism ensures a sustainable industry that contributes to Marine Park management.

While nearly three-quarters of tourist visitor days are carried by the 50 major tourism operators, there are some 900 current permits in total. This latent capacity is successfully managed in high use areas (which support 85 per cent of tourism activity) through capping permits for everyday access and a booking system for operators who are not permitted everyday access.

There are high levels of visitor satisfaction about the Great Barrier Reef tourism experience and the industry provides significant economic benefits to local communities.

Tourism stakeholders are well known to managers and engaged through the Tourism and Recreation Reef Advisory Committee, Local Management Advisory Committees and tourism industry bodies.

The Environmental Management Charge paid by each tourist to the Great Barrier Reef Marine Park provides almost 20 per cent of the overall budget of the Great Barrier Reef Marine Park Authority. Skills and expertise in management agencies are augmented through industry partnerships and tour operators are involved in data collection relevant to both biophysical and socio-economic values.

6.2.5 Defence

The limited area of operations combined with thorough assessment, coordination and planning results in defence activities posing minimal threat to Great Barrier Reef values.

Responsibility for the conduct of training activities by the defence forces, including visiting overseas defence force members, lies with the Australian Department of Defence. This includes the management of the environmental impacts of those activities subject to the application of the zoning plans.

Defence activities are allowed under the *Great Barrier Reef Marine Park Zoning Plan 2003*. A management agreement between the Department of Defence and the Great Barrier Reef Marine Park Authority ensures a shared understanding of potential threats, external influences and key stakeholder issues. Strategic documents, policies and regular meetings facilitate implementation of the management agreement and ensure consistency of approach with other management agencies. Training exercises are thoroughly planned and include good performance monitoring, debriefs and post exercise monitoring. Appropriate Department of Defence resources are devoted to environmental management, staff exchanges, secondments and joint patrols.

Thorough assessment, coordination and planning mean that defence activities are well managed in the Great Barrier Reef.

Local communities are successfully engaged in planning for specific exercises and routinely through Defence Environmental Advisory Committees. The knowledge base of defence activities in the Great Barrier Reef, both within the management agencies and in the wider community, has increased in recent years as a result of consultative meetings and reports documenting efforts to minimise environmental impacts.

6.2.6 Fishing (commercial and recreational)

Fishing is the principal extractive use of the Great Barrier Reef. Management of fishing and its environmental impacts is shared between the Australian and Queensland Governments.

Most fisheries operate at a scale greater than the Great Barrier Reef. The Queensland Government manages them by input and output controls often as part of formal management plans. The Great Barrier Reef's values are frequently the driver of policy responses, although these values are not necessarily explicitly addressed.

The provisions of Marine Park zoning plans set out the areas where different types of fishing can be undertaken consistent with the management objectives for each zone. However zoning plans, although providing complementary arrangements, are not intended to manage fisheries effort or the size or type of fish taken.

Although there is a comprehensive legislative framework at the Commonwealth and State level to manage fisheries, there is no systematic cross jurisdictional approach to address regional issues, cumulative impacts and how these interact with World Heritage obligations. In a World Heritage Area, it is expected that particular attention would be paid to the application of the precautionary principle in deciding acceptable levels of fisheries take. Protection of Great Barrier Reef values relevant to fishing is variable and progress towards application of best practice management across the whole fisheries spectrum is being made, but not rapidly. In addition, management systems are not adaptive enough to deal with the pace of change or any compounding issues arising from climate change and water quality impacts.

Knowledge of trends in fish stocks are variable between species with the commercial catch of some species trending down over recent years. Physical habitats are generally well protected by zoning plans.

Commercial export fisheries in the Great Barrier Reef are accredited against national sustainability guidelines, which include an assessment of impacts on World Heritage values. The large and more diffuse recreational sector poses a management challenge to ensure overall ecosystem sustainability. Arrangements to manage recreational fishing for a number of inshore species were revised in December 2008. Therefore, the effectiveness of the new measures cannot be meaningfully assessed at this time.

A lack of information and coordination, plus variable uptake of best practice management, is limiting the effectiveness of fisheries management.

Managers generally have a good understanding of commercial retained catch, but information is gathered on a risk-based approach and generally focused on a number of targeted species and habitats. There is limited information on the biology and stock distributions of non-target species as well as on the habitat values and broader cost/benefit analyses of the industry. The understanding of recreational fishing and the take by charter and Indigenous fishers is much more limited. Cumulative impacts on the ecosystem are poorly understood and hence not effectively addressed in management. Very little information is available on the number and fate of species of conservation concern caught in fishing operations. The timely application of new knowledge to decision making is limited and variable.

While resourcing is generally secure at low levels, population growth and concurrent potential growth in recreational fishing are increasing management needs particularly with regard to ecosystem-based assessments and compliance monitoring. Long-term monitoring is funded by the Queensland Department of Employment, Economic Development and Innovation. Monitoring and stock assessments are routinely completed for a limited number of targeted species, based on the potential risk to the species and related impacts. Research funding is generally dependent on grants, with insufficient security to support long-term studies and trend analysis.

Engagement with stakeholders through consultation processes and advisory committees is generally good, especially for commercial fishing. Effective collaboration in management efforts is particularly challenging in the diffuse recreational fishing sector and with Indigenous fishers.

Marine-based aquaculture within the Great Barrier Reef Marine Park and Great Barrier Reef Coast Marine Park is a tightly controlled and very limited activity. Managers have a sound knowledge base regarding in-Park aquaculture and generally understand the risks and threats it presents. Current management arrangements, plans and allocated resources are considered appropriate to deal with new proposals and any likely increase in activity. The management of land-based aquaculture is considered as part of the water quality management topic (Section 6.2.12).

6.2.7 Heritage

The Great Barrier Reef Marine Park covers 99 per cent of the World Heritage Area, and many of its islands and most intertidal areas are protected by Queensland Government legislation. The Department of the

Environment, Water, Heritage and the Arts is the lead agency for the coordination and oversight of Commonwealth heritage issues and the Queensland Department of Environment and Resource Management for matters within Queensland jurisdiction.

Management of heritage is complex but there is a good understanding across jurisdictions of the biophysical, cultural (including Indigenous), historic and socio-economic values of the Great Barrier Reef and specific stakeholders with an interest in cultural and historic heritage are well known to managers.

There is strong awareness of heritage values and protection arrangements are in place.

A Heritage Strategy has been developed by the Great Barrier Reef Marine Park Authority addressing the requirements set out under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*. This strategy provides guidance for protection of Great Barrier Reef Marine Park heritage values through an array of planning instruments and policies. Management and governance processes are in place to support implementation of the Heritage Strategy; however the Strategy does not set a timetable for implementation or indicate relative priorities. Historic shipwrecks are protected through specific legislation and entry controls.

The negotiation of Traditional Use of Marine Resources Agreements (TUMRAs) and the work of Indigenous liaison staff help ensure that Indigenous heritage issues are addressed although knowledge appears lacking about the broader context of intangible Traditional Owner heritage including traditional knowledge and maintenance of cultural practice.

Limited financial and human resources are generally available for protection of heritage and specialist expertise is not always available in management agencies. Agencies are improving skills in Indigenous heritage management and increasing Indigenous engagement.

6.2.8 Ports and shipping

Shipping in the Great Barrier Reef is managed by several government agencies including the Australian Maritime Safety Authority, Maritime Safety Queensland, the Great Barrier Reef Marine Park Authority and the Commonwealth Department of Infrastructure, Transport, Regional Development and Local Government. Port management is the responsibility of the Queensland Government.

Ports and shipping pose different suites of issues for the Great Barrier Reef ecosystem. Consideration of matters around port establishment and management overlaps with coastal development. In contrast, shipping management is focused on reducing the risk of incidents.

The system of navigation aids, communications, shipping incident response plans and environmental management plans for port facilities demonstrates recognition of the values of the Great Barrier Reef and the sensitive environments in which ships are moving.

Comprehensive management and coordination has minimised shipping incidents.

With regard to shipping, the rules are uniform nationally and there is high-level coordination of everyday activities and incident response. Comprehensive management arrangements mean that there have been few incidents threatening Great Barrier Reef values relative to the large number of shipping movements in and through the Region. Many agencies are engaged in risk-based planning related to shipping and some risks, such as those posed by increased ship size, are recognised. However other risks, such as those posed by biofouling, ballast water discharges and containerised chemicals, are not yet fully addressed and progress on these issues has been slow.

While planning to address the growth and long-term impacts of ports and shipping activities is underdeveloped, there is good planning at the individual port level. Most planning for ports and shipping appears to be responsive rather than strategic and proactive. The independence of individual port corporations makes consistency across jurisdictions a challenge, especially when it comes to addressing cumulative or compounding impacts. Environmental management practices in many ports appear to be limiting impacts of port activities. Individual port corporations have substantial resources and appropriately qualified and experienced staff.

Within management agencies there is uncertainty about expected workloads associated with any growth in ports and shipping. There are dedicated resources for pollution incident prevention and response but monitoring for introduced pests is expensive and not adequately defined, funded or implemented.

The complexity of tasks and coordination across jurisdictions has resulted in limited strategic leadership and planning to address the growth and long-term environmental impacts of ports and shipping activities. This may impact on environmental sustainability in the future.

6.2.9 Recreation (not including fishing)

Management of recreation is generally indirect and coordination is lacking.

The values of the Great Barrier Reef that attract large numbers of recreational visitors are well documented and threats to those values such as population pressures, increased vessel registrations, marinas and small vessel sewage discharges have been identified by management agencies. Wider influences such as increasing numbers of super-yachts, climate change and changes in travel patterns have also been identified.

The responsibility for management of non-extractive recreation is spread across a variety of Australian and Queensland Government agencies. Principal among these are the Great Barrier Reef Marine Park Authority, the Queensland Department of Environment and Resource Management and Maritime Safety Queensland.

The threats of recreational use (not including fishing) are generally being reduced through zoning plans, plans of management, policies and guidelines such as Responsible Reef Practices and day-to-day field operations. Concerns remain about issues such as the impacts of vessel anchoring and sewage discharge in sensitive areas. Limited resources are allocated explicitly to the management of recreation activities other than fishing and management is generally indirect and implicitly undertaken as part of routine field operations. There is little monitoring of recreational impacts.

Coordination between management agencies on recreation is lacking and there is no overarching strategy to guide planning for recreational use of the Great Barrier Reef. In turn, a lack of targeted management objectives makes assessment of effectiveness difficult; however it is clear that quality recreation products and services have been provided with high satisfaction ratings from recreational visitors.

Enhanced activity on community engagement has resulted in improved skills and expertise for management agency staff dealing with recreational users of the Great Barrier Reef. Extensive programs such as volunteer groups and Reef Guardian Schools have provided opportunities for wider involvement in management of recreation-related issues.

6.2.10 Scientific research

The Great Barrier Reef supports a large amount of research, funded from multiple sources. This evaluation of the effectiveness of management in relation to scientific research concentrates on the management of research in the Great Barrier Reef through permits and accreditation mechanisms. The wider questions of the availability and application of knowledge gained from scientific research are separately considered under the other management topics.

Research activities in the Great Barrier Reef Region are generally considered to be environmentally sustainable and, through the maintenance of effective partnerships with research institutions, are demonstrably enhancing community understanding and enjoyment of the Great Barrier Reef.

Research activities are environmentally sustainable and are enhancing community understanding.

Robust management processes and governance arrangements are in place to manage research in the Great Barrier Reef with the Great Barrier Reef Marine Park Authority, Queensland Department of Environment and Resource Management and Queensland Department of Employment, Economic Development and Innovation as the lead agencies. Statutory regulations, the zoning plans and specific policies guide the management of research. There are co-accreditation arrangements to ensure consistency between jurisdictions and permits require stakeholder and local community engagement as necessary. Risks and threats to Great Barrier Reef values from research activities are recognised and reflected in the Scientific Research Policy of the Great Barrier Reef Marine Park Authority.

Staff in management agencies have sufficient research skills and expertise to effectively manage research activities in the Great Barrier Reef. However, resources for the management of research activities are limited.

6.2.11 Traditional use of marine resources

The timeframes available for the preparation of this Report did not present an opportunity to consult widely with Indigenous communities on the effectiveness of activities to manage traditional use of marine resources by Indigenous people. Consequently, this assessment relies solely on publicly available documents and consultation with Indigenous liaison staff of managing agencies.

Improvements are being made in the management of traditional use, including through joint resource use agreements, but progress is slow.

Progress by management agencies in the management of traditional use of marine resources has been slow, although management and consultation processes are helping to reduce some of the major risks to Great Barrier Reef values. In general, management processes exist in relation to the traditional use of marine resources, but matching the most appropriate mechanism to the specific situation is a challenge.

By the end of 2008, four Traditional Use of Marine Resources Agreements (TUMRAs) had been accredited by the Great Barrier Reef Marine Park Authority and Queensland Government. However, these do not cover those areas where the take of dugongs is highest and the negotiations are likely to be most difficult. While the pace of negotiation and implementation is driven largely by Traditional Owners rather than by government or agency timelines, there remains limited capacity within management agencies to deal with the simultaneous development of a number of TUMRAs.

Complementary zoning and almost identical provisions for traditional use across marine park jurisdictions are matched by strong consistency on commitment and outcomes, though there is limited consistency on mechanisms for delivery. The effectiveness of engagement of stakeholders and local communities is highly variable.

The complexities associated with this issue are well appreciated by managers, especially as they relate to harvesting of threatened and migratory species and the interaction between cultural sensitivities and other management imperatives. Financial and staffing resources for effective management of traditional use are currently deficient in relation to the size of the management task. The Indigenous element of the Australian Government's *Reef Rescue Plan* has recognised the need to provide additional resources for the period to 2013.

The knowledge base in agencies relevant to traditional use has increased in recent years.

6.2.12 Water quality

The overall legislative mandate for the management of water quality in the Great Barrier Reef catchment falls to the Queensland Government, principally through the Department of Environment and Resource Management.

To address the issue of declining water quality of the Great Barrier Reef, a *Reef Water Quality Protection Plan* (Reef Plan) was endorsed by the Prime Minister and Premier in October 2003. An independent audit and report to the Prime Minister and the Premier of Queensland on the implementation of Reef Plan was undertaken in 2005. Whilst the positive outcomes that were achieved over the last five years have been recognised, input from stakeholders and new scientific evidence confirmed the need to renew and reinvigorate the Reef Plan to ensure the goals and objectives will be met. As a result, an updated Reef Plan is being developed in consultation with stakeholders.

Overall, slow progress is being made towards improving the quality of water entering the Great Barrier Reef.

On the evidence provided for this assessment, it is unlikely that the goal of halting or reversing the water quality decline by 2013 will be achieved to a level that would lead to the desired improvement in ecosystem health and resilience. There has been little reduction in major risks to Great Barrier Reef values although it is hard to be sure because of the limitations of monitoring. Current activities in the coastal catchments are not demonstrably environmentally sustainable. Nor are they clearly economically sustainable, given the high value placed on maintaining an intact and functional reef ecosystem and the extent of the values jeopardised by poor water quality.

Values related to water quality, especially as influenced by agricultural runoff from coastal catchments are well documented in the *Reef Water Quality Protection Plan* and associated documents. Particular risks and threats arising from the estimated more than four-fold increase in sediments and nutrients since European settlement and the loss of catchment wetland areas are understood by managers.

A comprehensive planning system is in place centred on the *Reef Water Quality Protection Plan* with clearly documented objectives but delivery within the planning framework is lacking. The *2007 Water Quality Report: Great Barrier Reef catchments and inshore ecosystems* indicates that there is still a need for better implementation of the *Reef Water Quality Protection Plan*.

Substantial resources are being provided to improve the water quality of the Great Barrier Reef, but progress is slow and patchy.

Introduction of the *Great Barrier Reef Marine Park (Aquaculture) Regulations 2000* resulted in a significant improvement in the environmental performance of land-based aquaculture facilities. Subsequent assessment and compliance auditing of these facilities by the Great Barrier Reef Marine Park Authority indicates substantial compliance with environmental conditions.

There have been many delays in the development and implementation of regional plans, with Water Quality Improvement Plans in place for only six of the ten priority catchments. At the same time, comprehensive land use planning is not sufficiently focused on water quality protection. Actions for implementation are identified at a high level though identification at the farm scale is lacking. While required policies are largely in place and engagement is increasing, rural industries and land managers are not fully engaged and sectoral consistency is lacking.

Considerable financial and human resources are allocated to addressing the water quality issue from various sources. Significant funding from the Australian and Queensland Governments is now in place, totalling in excess of $400 million over five years. While this funding is considered secure, other funding, especially for Natural Resource Management Bodies is not secure, is usually time limited and project specific.

Management agencies have the required skill sets and expertise available and good biophysical information is generally available. However, this information comes from disparate and incomplete data sources and the coordination and delivery of science into management processes is inadequate. There are knowledge gaps around production systems, nutrient loss at the sub-catchment level and, while water quality improvement plans are looking at socio-economic drivers, the information is not well coordinated. There is limited monitoring of inshore waters, very little catchment monitoring and very patchy monitoring of changes in land use practices. Cumulative impacts from major agricultural activities are considered, although chemical interactions along with cumulative and compounding impacts of non-agricultural activities are not addressed. There is insufficient information available on the implications of changes in land use practices.

Water quality standards are identified but are not being met in some vulnerable inshore locations.

Community surveys show good understanding of the problem of declining water quality, but not necessarily the solutions. The community knowledge base has increased, especially where water quality improvement plans are in place and there are high levels of volunteer involvement in fieldwork and monitoring programs. Indigenous interest in land management is generally well understood.

6.3 Assessment summary - Existing protection and management

Section 54(3)(f) of the *Great Barrier Reef Marine Park Act 1975* requires '*…an assessment of the existing measures to protect and manage the ecosystem* …' within the Great Barrier Reef Region. The assessment was undertaken by two independent external expert assessors based on six assessment criteria:

- understanding of context
- planning
- financial, staffing and information inputs
- management systems and processes
- delivery of outputs
- achievement of outcomes.

6.3.1 Understanding of context

Assessment criterion	Summary	Assessment Grade: Very good	Good	Poor	Very poor
Understanding of context	Understanding of values, threats, national and international influences and stakeholders is strong for all management issues assessed. This reflects a solid information and research base and a very mature understanding of the key values of the Great Barrier Reef in both a national and international context and the actual and potential threats to those values. Understanding of stakeholders is consistently strong across all issues (in fact, it shows the strongest performance across the entire range of assessment criteria).	●			

GRADING STATEMENTS

Very good - Understanding of values, threats, regional/global influences and stakeholders is good for most management topics.

Good - Understanding is generally good but there is some variability across management topics or components.

Poor - Understanding of values, threats, regional and global influences and relevant stakeholders is only fair for most management topics.

Very poor - Understanding of values, threats, regional and global influences and relevant stakeholders is poor for most management topics.

6.3.2 Planning

Assessment criterion	Summary	Assessment Grade: Very good	Good	Poor	Very poor
Planning	Planning performance tends to be strongest where there are few organisations or levels of governance involved in the planning process. There are well developed planning systems in place for all issues except for coastal development where the fractured nature of the planning regime causes problems. Lack of consistency across jurisdictions is the weakest aspect of planning.		●		

GRADING STATEMENTS

Very good - Effective planning systems that engage stakeholders are in place for all or most significant issues. There is adequate policy to manage issues that is consistent across jurisdictions.

Good - Effective planning systems that engage stakeholders are in place for many significant issues. Policy and consistency across jurisdictions is generally satisfactory.

Poor - Planning systems that engage stakeholders are deficient for a number of significant issues. Policy and consistency across jurisdictions is a problem for some issues.

Very poor - Planning systems that engage stakeholders are deficient for many significant issues. Policy and consistency across jurisdictions is a problem for some issues.

6.3.3 Financial, staffing and information inputs

Assessment criterion	Summary	Assessment Grade: Very good	Good	Poor	Very poor
Financial, staffing and information inputs	Adequacy of inputs is quite variable across the management issues, being particularly strong for defence, climate change and research and weak for coastal development. Adequacy of socio-economic and access to relevant Traditional Owner knowledge is a problem for most issues and one of the worst performing criteria across the whole assessment.			●	

GRADING STATEMENTS

Very good - Financial and staffing resources are largely adequate to meet management needs. Biophysical, socio-economic and Traditional Owner knowledge is available to inform management decision making.

Good - Financial and staffing resources are mostly adequate to meet management needs. Biophysical, socio-economic and Traditional Owner knowledge is mostly available to inform management decision making although there may be deficiencies in some areas.

Poor - Financial and staffing resources are unable to meet management needs in some important thematic areas. Biophysical, socio-economic and Traditional Owner knowledge is variably available to inform management decision making and there are significant deficiencies in some areas.

Very poor - Financial and staffing resources are unable to meet management needs in many thematic areas. Biophysical, socio-economic and Traditional Owner knowledge to support decision making is frequently deficient in some areas.

6.3.4 Management systems and processes

Assessment criterion	Summary	Assessment Grade: Very good	Good	Poor	Very poor
Management systems and processes	Management processes are particularly strong for defence, tourism and research and weakest for coastal development and water quality. Performance monitoring, addressing cumulative impacts and application of socio-economic and Traditional Owner knowledge are a problem for most issues. The extent to which cumulative impacts are being addressed is the weakest indicator across the entire assessment. Stakeholder engagement and application of biophysical information are amongst the strongest aspects of management across all issues.		●		

GRADING STATEMENTS

Very good - The majority of management processes are appropriate and effective in addressing the management of the various management topics.

Good - The majority of management processes are appropriate and effective in addressing management although there are deficiencies in relation to a small number of management topics or processes.

Poor - A minority of critical management processes show significant deficiencies across most management topics.

Very poor - A majority of management processes show significant deficiencies across most management topics.

6.3.5 Delivery of outputs

Assessment criterion	Summary	Assessment Grade: Very good	Good	Poor	Very poor
Delivery of outputs	Delivery of desired outputs is weakest for coastal development and water quality and strongest in relation to defence, tourism and research. The knowledge base of the management agencies and community has consistently improved. While the majority of management programs are progressing satisfactorily (with the exception of coastal management and water quality), timeframes frequently slip and it is not yet clear that the programs are achieving all their desired objectives.		◉		

GRADING STATEMENTS

Very good - Management programs are mostly progressing in accordance with planned programs and are achieving their desired objectives. The agency and community knowledge base is improving.

Good - Management programs are mostly progressing in accordance with planned programs and are achieving their desired objectives but there are problems in some management topics. The agency and community knowledge base is generally improving.

Poor - Many management programs are not progressing in accordance with planned programs (significant delays or incomplete actions) or actions undertaken are not achieving objectives. The knowledge base is only growing slowly.

Very poor - Most management programs are not progressing in accordance with planned programs (significant delays or incomplete actions) or actions undertaken are not achieving objectives. The knowledge base is only growing slowly.

6.3.6 Achievement of outcomes

Assessment criterion	Summary	Assessment Grade: Very good	Good	Poor	Very poor
Achievement of outcomes	Achievement of desired outcomes (values protected, threats reduced, long-term environmental and economic sustainability) is very variable across issues. Objectives in relation to community understanding of issues and development of effective partnerships are being achieved. Overall, greatest concern in relation to achievement of desired outcomes relates to climate change.			◉	

GRADING STATEMENTS

Very good - Desired outcomes are mostly being achieved, values protected and threats abated for most thematic areas. Use of the Great Barrier Reef is largely environmentally and economically sustainable with good community engagement, understanding and enjoyment.

Good - Desired outcomes are being achieved in many management topics, values protected and threats abated for many management topics. Use of the Great Barrier Reef is largely environmentally and economically sustainable with good community engagement, understanding and enjoyment.

Poor - Desired outcomes, protection of values and abatement of threats are not being achieved at desirable levels in some critical management topics with likely eventual flow-on effects across the Great Barrier Reef. Critical aspects of the use of the Great Barrier Reef are not environmentally or economically sustainable.

Very poor - Desired outcomes, protection of values and abatement of threats are not being achieved at desirable levels in most management topics including critical areas with likely eventual flow-on effects across the Great Barrier Reef. Critical aspects of the use of the Great Barrier Reef are not environmentally or economically sustainable.

6.3.7 Overall summary of existing protection and management

The effectiveness of existing measures to protect and manage the Great Barrier Reef ecosystem was independently assessed for 12 broad management topics, ranging from biodiversity protection to fishing, coastal development and ports and shipping (figure 6.5).

Management effectiveness challenges are evident for those management topics which are broad in scale and complex socially, biophysically and jurisdictionally (for example climate change, coastal development, water quality and fishing). Effectiveness is strongest on issues that are limited in scale, intensity or complexity (for example defence and scientific research).

The outcomes for each of the six Assessment Criteria examining all of the broad management topics combined are summarised in figure 6.5.

Management topic	Scale	Complexity: Social	Complexity: Biophysical	Complexity: Jurisdictional	Summary	Context	Planning	Inputs	Processes	Outputs	Outcomes
Coastal development	Coastal catchment areas and mainly inshore waters	major	major	major	A lack of integrated planning, resources and enforcement in managing coastal development is compromising protection of the Great Barrier Reef.	Good	Poor	Poor	Poor	Poor	Poor
Water quality	Great Barrier Reef catchment and mainly inshore waters	major	major	major	Substantial resources are being provided to improve the water quality of the Great Barrier Reef, but progress is slow and patchy.	Very good	Good	Good	Poor	Poor	Poor
Fishing	Region-wide but variable in intensity	major	major	moderate	A lack of information and coordination, plus variable uptake of best practice management, is limiting the effectiveness of fisheries management.	Good	Good	Poor	Good	Good	Poor
Climate change*	Region-wide	major	major	major	The broad threats to the Great Barrier Reef from climate change are understood and management emphasis is on adaptation and improving resilience to change.	Very good	Good	Good	Good	Good	Poor
Traditional use of marine resources	Region-wide but variable in intensity	major	moderate	moderate	Improvements are being made in the management of traditional use, including joint resource use agreements, but progress is slow.	Very good	Good	Poor	Good	Good	Good
Recreation (not including fishing)	Region-wide but variable in intensity	major	moderate	moderate	Management of recreation is generally indirect and coordination is lacking.	Very good	Good	Good	Good	Good	Good
Biodiversity protection	Region-wide	minor	major	moderate	Many biodiversity protection measures, for example zoning plans, are making a difference, but there is no overarching framework to guide and coordinate management actions.	Very good	Good	Good	Good	Good	Good
Heritage	Region-wide	moderate	minor	moderate	There is strong awareness of heritage values and protection arrangements are in place.	Very good	Very good	Good	Good	Good	Good
Ports and shipping	Concentrated around ports and shipping lanes	moderate	moderate	moderate	Comprehensive management and coordination has minimised shipping incidents. Ports management appears to have protected natural values, but there is a lack of overall strategic planning.	Very good	Good	Good	Good	Good	Very good
Commercial marine tourism	Region-wide but variable in intensity	major	moderate	moderate	Coordinated and professional management of tourism ensures a sustainable industry that contributes to Marine Park management.	Very good	Very good	Good	Very good	Very good	Very good
Defence	Limited in area and duration	minor	minor	minor	Thorough assessment, coordination and planning mean that defence activities are well managed in the Great Barrier Reef.	Very good	Very good	Very good	Very good	Very good	Very good
Scientific research	Region-wide but limited in intensity	minor	moderate	minor	Research activities are environmentally sustainable and are enhancing community understanding.	Very good	Very good	Very good	Very good	Very good	Very good

Effectiveness of existing measures to protect and manage: Very good | Good | Poor | Very poor

Figure 6.5 Overall assessment of the effectiveness of existing measures to protect and manage the Great Barrier Reef ecosystem

The Grading Statements for each of the Assessment Criteria are provided in Section 6.3.1 to 6.3.6. (*)The assessment of management effectiveness for the topic of climate change is only in relation to management measures undertaken specifically to protect and manage the Great Barrier Reef.

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1 Australian Government 2006, Review of the *Great Barrier Reef Marine Park Act 1975*: Review Panel Report. Department of Environment and Heritage, Canberra, Australia.

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ECOSYSTEM RESILIENCE

CHAPTER SEVEN

"Nature's restorative operations are performed unceasingly, with never-failing design and often with the exhibition of wonderful power ...."

E.J. Banfield, 1925
Journalist, naturalist and beachcomber

"...an assessment of the current resilience of the ecosystem...", within the Great Barrier Reef Region, Section 54(3)(e) *Great Barrier Reef Marine Park Act 1975*

7 ECOSYSTEM RESILIENCE

7.1 Background

A resilient ecosystem can withstand shocks and pressures and rebuild itself.

Ecosystem resilience refers to the capacity of an ecosystem to recover from disturbance or withstand ongoing pressures.[1 2] It is a measure of how well an ecosystem can tolerate disturbance without collapsing into a different state that is controlled by a different set of processes. Resilience is not about a single ideal ecological state, but an ever-changing system of disturbance and recovery.

Coral reef and other tropical marine ecosystems are subject to frequent disturbances, from threats such as cyclones, crown-of-thorns starfish outbreaks and influxes of freshwater as well as from a range of human activities. These events often damage, stress or kill components of the ecosystem. Given enough time, a resilient ecosystem will be able to fully recover from such disturbances and become as biodiverse and healthy as before the impact. Similarly, a resilient ecosystem may be able to absorb the stresses caused by these disturbances with little or no sign of degradation.

The Great Barrier Reef ecosystem is facing some very serious threats. An understanding of the ecosystem's resilience - its ability to absorb or recover from these threats - is an important part of predicting its likely outlook.

7.1.1 Factors that affect resilience

Ecosystem resilience is complex to understand and assess because a number of factors can affect it.[2 3 4] An ecosystem's ability to absorb or recover from impacts, and its rate of recovery, depend on the inherent biology and ecology of its component species or habitats; the condition of these individual components; the nature, severity and duration of the impacts and the degree to which potential impacts have been removed or reduced. If all of these features are in place, populations of species or habitats can often absorb or recover from impacts, thus allowing the ecosystem to continue to function. However, if any limitations exist, the capacity of the ecosystem to absorb impacts without changing will be lower than optimal and recovery will take much longer, or even fail.

The key features on which to base an assessment of ecosystem resilience can be grouped as:

Ecosystem biodiversity The variation contained within species and between species and the condition of populations of species and their habitats can be a key factor in resilience.

- It is generally considered that the greater the biodiversity of an ecosystem, the greater the likelihood that an organism can perform a different ecological role when the ecosystem is under pressure (known as 'functional redundancy') and thus adapt to changing ecological conditions.[2]
- Shifts in an ecosystem's biodiversity may indicate that the system is under pressure. For example, a coral reef habitat with a diverse array of corals and fish and a relatively low abundance of fleshy algae usually indicates a habitat that is in relatively good condition. Pressures, such as overfishing, excess nutrients and ocean warming will often cause a long-term shift towards abundant algae and few corals (known as a phase shift).
- The rate at which a species is able to recover within an ecosystem is limited by its biology and ecology. Species can only breed when they reach adulthood, which, in the Great Barrier Reef, can range from five weeks for the pigmy goby (the shortest known vertebrate life history)[4] to over 40 years for green turtles. Some species may require specific breeding areas or conditions (e.g. temperature, phase of the moon or day length) before they are successful in reproducing; for example, coral spawning occurs one to six nights after the full moon in October. Some species may breed annually, some at intervals of five or more years.

The current state and trends of biodiversity in the Great Barrier Reef ecosystem are presented in Chapter 2.

Ecosystem health Natural functioning of an ecosystem's physical, chemical and ecological processes is likely to result in a resilient ecosystem that can absorb stress and rebuild after disturbances. For example:

- Coral recruitment is likely to be strong at reefs with intact herbivore populations because the ecological equilibrium between corals and algae is largely determined by the ecological process of herbivory[5 6](Section 3.4.4).
- The replenishment of fish and coral larvae between and within habitats requires ocean circulation patterns (Section 3.2.1) to maintain connectivity (Section 3.4.9).[7 8]

In assessing resilience, it is important to remember that ecosystems are complex, with countless inter-relationships and the effects of change are not always predictable. The effects of different impacts on an ecosystem often compound and magnify each other. Many ecological processes contain feedbacks that may either regulate or magnify changes.

The current state and trends of health in the Great Barrier Reef ecosystem are presented in Chapter 3.

Impacts on the ecosystem A number of factors affect ecosystems and in many ways, either individually or in combination and at various time and geographic scales.

- A resilient ecosystem will be able to recover from most of these impacts. However, chronic widespread impacts (such as climate change) can seriously affect the resilience of an ecosystem and even short-term local impacts (such as cyclones[9]) can affect resilience, especially when acting in combination with other impacts.
- Impact frequency is also critical to resilience because an ecosystem will always require time to recover from an impact. If recovery takes too long, or disturbances are too frequent or continual, the system may not fully recover before the next disturbance, leading to gradual, long-term degradation.[9 10]

The current and projected factors that are influencing the Great Barrier Reef Region are presented in Chapter 5.

Protection and management For an ecosystem that is already under pressure, the effectiveness of protection and management measures at addressing the threats to that ecosystem is an important factor in retaining or restoring resilience.

- This includes management actions both within the ecosystem and those addressing threats external to the ecosystem.
- The recovery of an ecosystem usually will be stronger if all of the threats are mitigated including those that may be short-term or localised. For example, if one activity has led to a decrease in the population of a species and that activity is removed, assuming all other ecosystem requirements can be met, the species should recover at its maximum population growth rate. However, if many impacts are affecting the species and not all are addressed, the species will not recover at its maximum rate, if at all.

The overall effectiveness of existing protection and management is assessed in Chapter 6.

7.1.2 Comparison with other coral reef ecosystems

There are many examples around the world where coral reefs, or other marine habitats, that lacked resilience have collapsed into a completely different state after being subjected to a range of pressures such as coastal development, poor water quality and fishing pressure.[10] Visitors to the Caribbean may now be diving on reefs that are dominated by algae, with only a few small corals.[10] A number of historically significant fisheries have collapsed and are not yet recovered, causing enormous social, economic and ecological consequences.[11] In countries where reef ecosystems suffer chronically increased sediment loads and where fishing pressures are high, reefs have only partially recovered or have become algae-dominated ecosystems.[12]

The overall condition of the Great Barrier Reef has been considered by a range of scientific experts from a variety of perspectives and their overall consensus is that, while the Great Barrier Reef has suffered significant degradation compared to its pristine condition, it is in far better health than most other reefs around the world (figure 7.1). In the Australia and Papua New Guinea region, 83 per cent of reefs are estimated to be at no immediate threat of significant losses (except for climate change) where as in the United States Caribbean and South-East Asia this percentage drops to 29 per cent and 15 per cent respectively.[13]

7.2 Case studies of recovery after disturbance

Recovery of species or groups of species is a function of their biology, the presence of suitable habitats and the absence of pressures on the species. Without addressing all pressures, recovery will either be slower than its maximum potential, or will not occur.

The following case studies showcase the extent to which some key functional habitats (coral reefs, lagoon floor) and ecological processes such as particle feeding (black teatfish), herbivory (urban coast dugong) and predation (coral trout) have demonstrated recovery after human and natural disturbances. They also showcase some specific management actions that have occurred to address declines in two species (loggerhead turtles, humpback whales).

These case studies are presented to provide examples of the resilience of the Great Barrier Reef ecosystem.

7.2.1 Coral reef habitats

Corals have a special role in reef recovery because they construct habitat for a variety of reef-dependent fish, invertebrates and plants. A coral reef ecosystem that has become damaged to the point where it is nothing but rubble offers little physical protection for small fish and most invertebrates. It is only when a three-dimensional habitat is rebuilt that the habitat can recover its full range of ecological functions.[5 15] Even then, there is a significant difference between an apparently recovered coral reef habitat (usually composed only of fast-growing *Acropora* coral species) and a fully recovered habitat (one that has the full diversity of corals). The former may show substantial re-colonisation within a few years whereas recovery of the full range of coral species, including massive corals and the associated coral reef species, may take decades, even centuries.[16]

In the Great Barrier Reef ecosystem, coral reef habitats are under pressure from a variety of human-related threats, including climate change, water quality, outbreaks of crown-of-thorns starfish, anchoring, dredging and ship groundings. Coral larvae are highly sensitive to water quality, especially sediment levels.[17]

Management A range of measures are used to either eliminate or substantially reduce the magnitude and likelihood of impacts on coral reef habitats. These measures include: protection of coral in Great Barrier Reef and fisheries legislation;

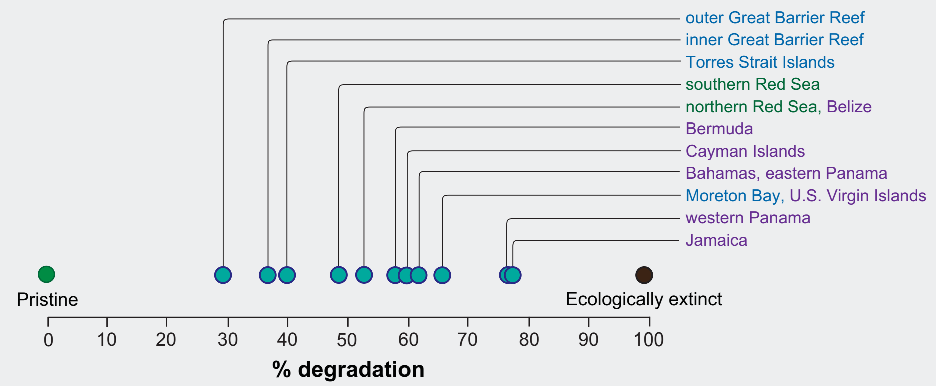


Figure 7.1 The degradation of coral reefs worldwide[14]

An independent analysis compared the relative extent of degradation of various coral reefs, based on the status of key groups of reef organisms. According to this analysis, the outer Great Barrier Reef, followed by the inner Great Barrier Reef and the Torres Strait (blue) are in better condition than reefs in the Red Sea (green) and the western Atlantic Ocean (maroon).

accreditation (with conditions) of the export component of the commercial coral harvest fishery under national sustainability guidelines; establishment of zones or special areas prohibiting certain activities; permit conditions for specific activities; guidelines and codes of conduct; Reef Protection Markers and moorings; implementation of activities to improve water quality (e.g. *Reef Rescue Plan, Reef Water Quality Protection Plan*), by reducing the runoff of terrestrial pollutants; and research and monitoring to assess impacts and monitor ecosystem condition.[18]

Evidence for recovery Corals on a resilient reef will gradually re-establish their dominance after disturbance, even though any dead coral may be initially, but temporarily, overgrown with macroalgae[19 20] (figure 7.2).

Under ideal conditions, coral reefs have an impressive ability to recover abundant coral cover within five to 10 years of single disturbances such as cyclones, crown-of-thorns starfish outbreaks (figure 7.3) or mass bleaching of corals (figure 7.4).

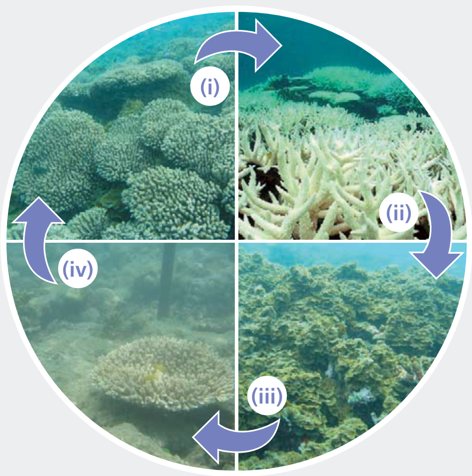


Figure 7.2 **Resilience of a coral reef habitat**

A healthy coral reef will recover from disturbances and return to its usual state. For example, in the Keppel Islands in 2006, abundant healthy corals (i) were bleached (ii), and subsequently overgrown by algae (iii). However, over the subsequent two years, surviving coral fragments regrew, and new corals settled and grew (iv), so that the reef is gradually returning to coral dominance (i). Human impacts may reduce the resilience of the system, and once disturbed, a less resilient ecosystem may fail to recover and may remain permanently in an algal dominated state (iii). (Photos i and iii by G. Diaz-Pulido, iv by L. McCook).

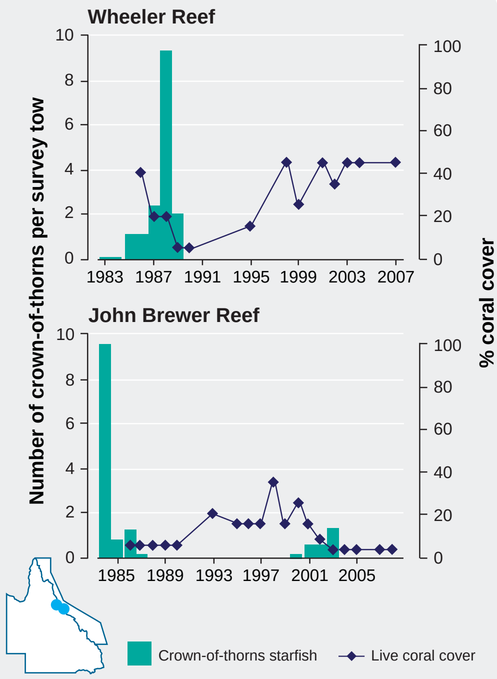


Figure 7.3 **Recovery of coral following disturbance by crown-of-thorns starfish[21]**

In the absence of other disturbances, coral reefs (such as Wheeler Reef) can show an increase in coral cover after an outbreak of crown-of-thorns starfish. On John Brewer Reef, the coral recovered after an outbreak of crown-of-thorns starfish in the 1980s but declined again after another outbreak.

Reefs can recover abundant coral cover within five to 10 years.

The recovery time of coral communities is strongly influenced by whether corals re-grow from existing colonies or rely on re-colonisation.[20] Crown-of-thorns starfish commonly leave parts of colonies untouched, which aids in recovery. In contrast, mass bleaching may kill whole colonies. In some cases, however, coral communities may recover rapidly from high coral mortality, as has recently occurred at the Keppel Islands (offshore Rockhampton) after a bleaching event (figure 7.4).

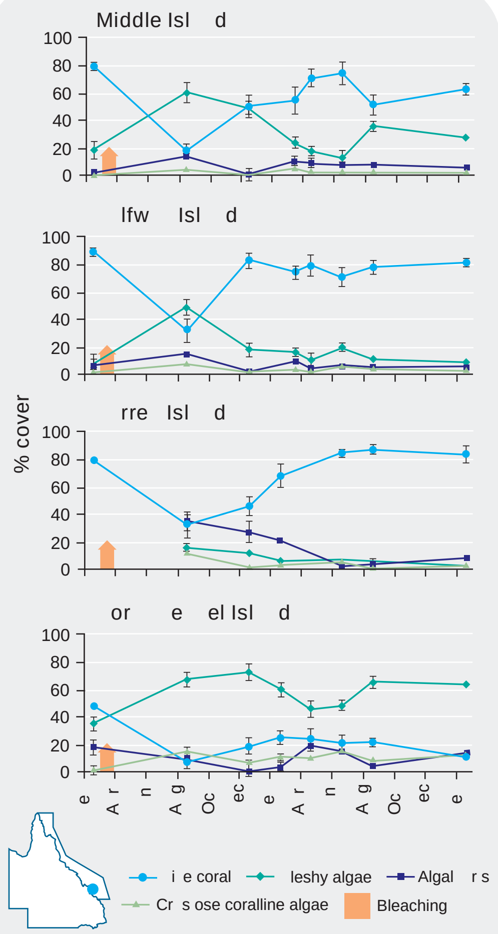


Figure 7.4 **Recovery of coral reefs at the Keppel Islands after a major bleaching event[20]**

A major coral bleaching event causing high coral mortality occurred in the Keppel Islands in 2006. For quick growing coral species, recovery from a disturbance, such as coral bleaching, can be very rapid. Recovery at North Keppel Island was weakest, possibly due to lower coral cover and higher cover of fleshy algae prior to the bleaching event and an increase in broken branching coral from bioerosion. The black bars indicate the standard error around the mean.

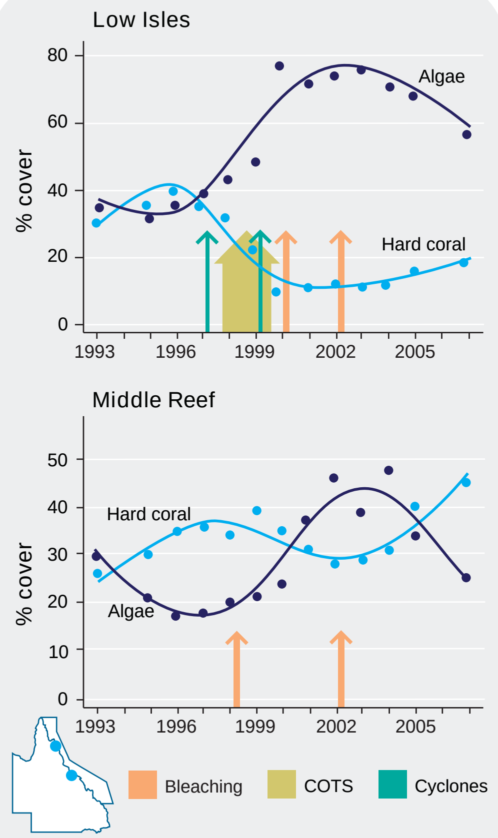


Figure 7.5 **Recovery of coral following various disturbances**

Multiple disturbances of bleaching, cyclones and crown-of-thorns starfish outbreaks (COTS), reduce the capacity of a reef to recover abundant corals, as seen in the slower recovery of hard coral at Low Isles. In comparison, Middle Reef experienced two bleaching events during the same time period and recovered well. (Adapted from Sweatman et al. 2008[21])

Coral reef habitats are recovering from multiple short-term disturbances.

The frequency of repeated disturbances such as cyclones, crown-of-thorns starfish outbreaks and flood events have kept some coral reefs of the Great Barrier Reef partly degraded for decades (figures 7.5 and 7.6).

Fish are essential to coral reef habitat recovery, not only in keeping macroalgae grazed but also in re-establishing other ecological processes, such as predation (for example by coral trout) and detritus recycling.

The projected vulnerability of coral reef habitats in the response to changing climate variables (Section 5.2.2), combined with degraded water quality continuing to enter the Great Barrier Reef (Section 5.4.2), means in the future coral reef habitats will face cumulative disturbance events more frequently and of increased severity. The recovery times of these habitats are likely to increase. Altered species composition of corals and the fish and invertebrates that depend on the habitat could have significant flow-on effects through the food web. Taken together, these factors suggest that the resilience of coral reef habitats on the Great Barrier Reef is declining.

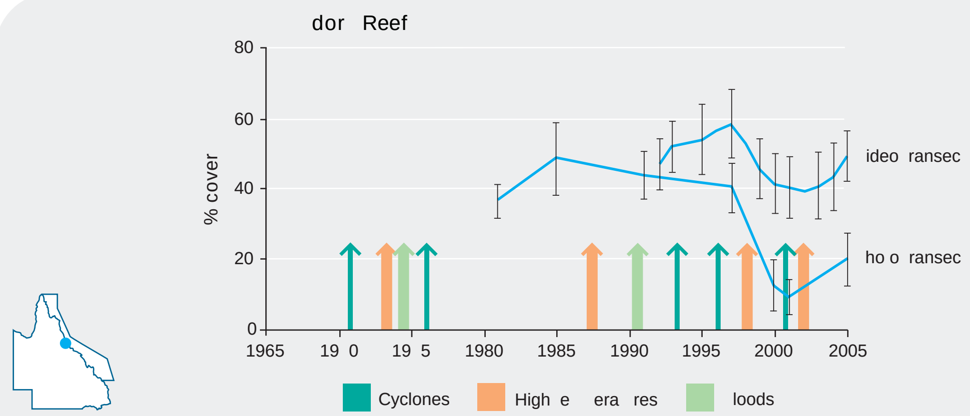


Figure 7.6 | **Recovery of coral reefs in inshore areas[22]**

The recovery of reefs depends on the frequency and nature of disturbances and the conditions for recovery. At Pandora Reef, an inshore reef north of Townsville, coral cover decreased in response to repeated disturbances and only increased once those disturbances ceased. The graph shows the percentage of coral cover (blue lines), measured by video and photo transects, in response to cyclones, high temperatures and floods. The black bars indicate the standard error around the mean.

Predicted increases in frequency and severity of disturbances will likely reduce the capacity for coral reefs to recover.

Success in recovering from a ship grounding

Michael Short from the **Queensland Department of Environment and Resource Management** has studied the recovery of coral reefs after ship groundings. He explains how site repairs and clean up has helped coral reefs recover:

"Since 1996 I have studied four ship grounding sites in the Great Barrier Reef, two where there has been extensive repair work and two with none. My research clearly shows that there are important advantages to stabilising the site where the ship has run aground … there is successful recruitment of coralline algae and juvenile coral and positive signs of successful coral reef recovery. However, at the sites that have not been repaired, the unstable nature of the area means the young corals are frequently damaged before they can contribute to reef recovery. As a result, it is likely to take many centuries for the coral to recover."

7.2.2 Lagoon floor habitats

The lagoon floor of the Great Barrier Reef is notably biodiverse, with more than 5000 species found in recent surveys of shallow benthic areas[23] (Section 2.2.3). Over the past 40 years, major impacts to the lagoon floor have included trawling (Section 4.4.3) and increased nutrients (Section 3.3.1) and pesticides (Section 3.3.2). The observable impacts from trawling have been quantified for a portion of the Region[24], whereas the effects of degraded water quality are more difficult to identify. For example, it can take years for the accumulation of pesticides to show effects in the ecosystem.

Management Today, the lagoon floor is managed in several ways. Marine Parks Zoning Plans protect representative examples of all habitats within the Great Barrier Reef ecosystem, with a minimum of 20 per cent of each of the 40 distinct non-reef bioregions (figure 2.3) protected.

Protection levels for all 840 recently identified seabed assemblages on the continental shelf of the Great Barrier Reef Region increased as a result of the 2004 rezoning of the Great Barrier Reef Marine Park.[25]

Managing risks from trawling in the Great Barrier Reef

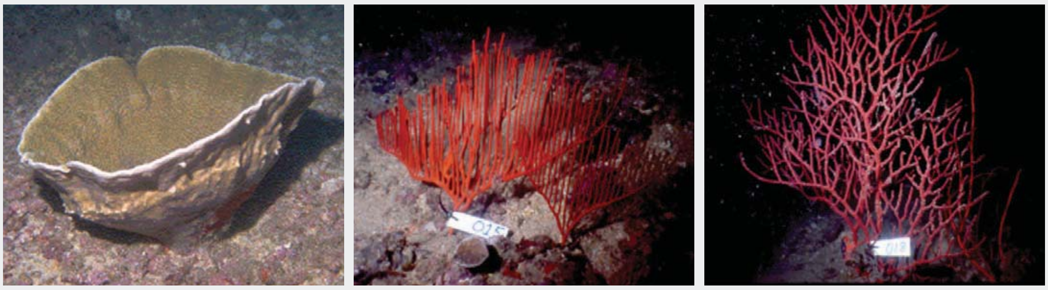
Management responses by the Queensland and Australian Governments and the fishing industry have substantially lowered the risk of trawling to the Great Barrier Reef ecosystem:

- The overall environmental footprint of the fishery is lower as a result of substantial reduction in fishing effort and fleet size.
- Trawling is allowed in 34 per cent of the Great Barrier Reef Marine Park and in 2005 occurred more than once a year in only six per cent (section 4.4.3).
- Investment in research has significantly improved the information base for the fishery and understanding of risks.
- Implementation of a satellite-based vessel monitoring system enables close monitoring of the fleet's activities, resulting in major benefits for compliance and fishery assessments.
- Mandatory use of turtle excluder devices and other bycatch reduction devices has reduced the impacts on bycatch, including species of conservation concern such as loggerhead turtles and large sharks.

Some lagoon floor habitats previously at risk are recovering from disturbances. Full recovery will take decades.

In addition to fishery management arrangements, the Queensland Government has declared 44 Fish Habitat Areas in or adjacent to the Great Barrier Reef, covering 741 813 hectares, to protect areas against physical disturbance from coastal development. A range of environmental impact assessment processes within Australian and Queensland Government legislation aim to minimise the impact of coastal development activities (e.g. dredging associated with port developments) on the lagoon floor. Measures to improve the quality of water entering the Great Barrier Reef, such as *Reef Rescue Plan* and the *Reef Water Quality Protection Plan*, are being implemented to reduce the runoff of terrestrial pollutants.

Evidence for recovery Experimental evidence indicates that some lagoon floor habitats have the potential to recover strongly after disturbances such as trawling.[24] Recovery rates vary: fast for some hard and soft corals and ascidians, moderate for a range of sponges, gorgonians and hard corals, slow for other sponge and gorgonian species (figure 7.7). The variability in recovery times (estimated to range from one to 64 years) depends on the intensity of trawling that has occurred[24] and the specific biology of the species (e.g. some reproduce or grow more rapidly). Although some individual species were shown to be recovering, the mix of species that make up the physical structure of the lagoon floor has changed over time, especially in those areas with higher trawl intensity or in deeper waters. Species assemblages in shallow water or in less intensively trawled areas are exhibiting signs of recovery.



Fast recovery
Hard coral
Turbinaria frondens

Moderate recovery
Gorgonian
Ctenocella pectinata

Slow recovery
Fan gorgonian
Subergorgia suberosa

Figure 7.7 | **Examples of lagoon floor species and their recovery rates[24]**

The location of this experiment, the far northern Great Barrier Reef, meant that other factors, such as degraded water quality, were considered unlikely to influence recovery. Obviously if impacts were occurring in addition to trawling, recovery times might be expected to be longer.

Ensuring that trawling is confined to the General Use Zone contributes to the recovery of lagoon floor habitats in other zones. However, records of trawling offences reported each year since the rezoning in 2004 indicates that a small number of trawlers continue to breach the management arrangements for the fishery (figure 4.15).

7.2.3 Black teatfish

Some species of sea cucumbers have been the focus of a commercial fishery in the Great Barrier Reef for more than 100 years[26] (Section 2.3.3). However, in 1999, the Queensland Government closed the fishery for one species, black teatfish, because of concerns for the long-term viability of the harvested stock. Populations of this species on fished reefs have been reduced by at least 75 per cent (to about five individuals per hectare).[27]

Black teatfish inhabit shallow waters. They spawn in winter and have limited migration between reefs. They are slow growing, have low recruitment and high survivorship as adults. These life history characteristics make the species susceptible to overfishing. It is estimated that an annual harvest as low as five per cent of the standing stock might be too great for the species on the Great Barrier Reef.[27]

Management Protection measures in addition to the fishery closure are limited to Marine Parks zoning, which protects a minimum of 20 per cent of all reef bioregions from extractive activities, including those inhabited by black teatfish.

Evidence for recovery For two years after the fishery was closed, reefs formerly fished and those unfished were surveyed to assess recovery of black teatfish. Results indicated no evidence of recovery in that period, with unchanged densities on both reefs that were previously open to fishing and those closed to fishing. Reefs that were already closed to fishing generally had four to five times the density of black teatfish than those that had been open to fishing.[27]

Recovery of this species is expected to be slow because of their life history characteristics and because they need to be close to each other to achieve fertilization after broadcast spawning. It is predicted that populations may take decades to recover.[28 29] These results are not only important for the species, but also for coral reef habitats, since sea cucumbers play an important role in mixing sediment particles and nutrient cycling. Ensuring the fishery and zoning closures are complied with will be a key determinant of recovery for this species.

Populations of black teatfish are low and are not recovering.

7.2.4 Coral trout

Coral trout are found on coral reef and shoal habitats within the Great Barrier Reef. Coral trout is the collective name used for several species of fish in the genus *Plectropomus*. They feed on other fish and invertebrates.[30] Adult coral trout are not thought to move great distances or between reefs, rather staying on resident reefs.[31] There is speculation that some coral trout species move greater distances when forming spawning aggregations, which happens around the new moons in Spring, as the water temperature increases. Little is known about movement of larvae between reefs; this topic is the subject of important current research.[32]

These life history traits mean that coral trout populations are influenced by the condition of coral reef habitats (Section 2.2.2) and the status of fishes (Section 2.3.5) and invertebrates (Section 2.3.3) that are their prey. In the future, coral trout may be influenced by increasing sea temperatures (Sections 3.2.6 and 5.2.1). Their spawning aggregation times and locations may alter, essential habitat may be affected by coral bleaching, and increasing ocean acidity may affect their habitats and the ability of larval fish to find and settle on reefs (Sections 3.3.3 and 5.2.1). Potential changes to ocean circulation could have major impacts on the supply of larvae to depleted populations.

Coral trout are a high-value food fish targeted by commercial and recreational fishers. Traditionally, they were marketed commercially either as fillets or as whole fish, but now most of the catch is sold in the Asian live fish trade.[33]

Management The Queensland Government manages the fishery focused on coral trout, primarily using the *Fisheries (Coral Reef Fin Fish Fishery) Management Plan 2003* and Regulations. In 2004, a total commercial allowable catch and spawning seasonal closures during the Spring new moons each year were introduced for coral trout. [34] There are also size limits and a limit on the number of fish that recreational fishers can have in their possession. The export of coral trout is accredited, with conditions, under national sustainability guidelines.

Marine Park zoning adds further management by protecting a representative portion of all reef habitats where coral trout live as well as the fish within these habitats and compliance patrols enforce the arrangements. Currently more than 65 per cent of the Great Barrier Reef is open to reef line fishing.

The number and size of coral trout is increasing rapidly in zones closed to fishing.

Evidence for recovery Surveys of coral trout on reefs recently closed to fishing have indicated an increase in numbers of up to 70 per cent within two years of closure (figure 7.8).[35] These closed reefs also have a significantly higher biomass of coral trout, because individual fish tend to be relatively large (figure 2.18). This is particularly important as large fish are disproportionally more fecund and therefore contribute most to future fish populations.[36]

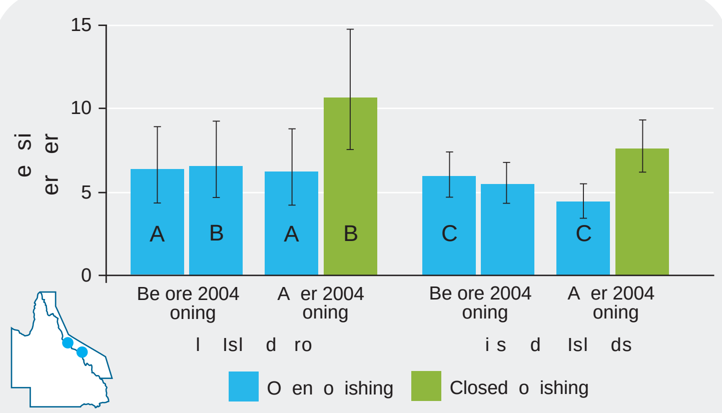


Figure 7.8 Density of coral trout on inshore reefs[35]

Abundance of coral trout can increase strongly once fishing pressure has been removed. In this study, the same sites were surveyed before and after the 2004 zoning. The removal of fishing pressure has also resulted in increases in the biomass of coral trout (figure 2.18). The black bars indicate the standard error around the mean.

The ecosystem effects of lower density and biomass of coral trout in zones open to fishing are largely unknown, particularly because the movement of adult coral trout between reefs is poorly understood; there is little understanding about how many spawning aggregations are protected by zoning; there is limited information on the extent to which closed reefs supply open reefs with coral trout larvae; and the flow on effects of losing predators, like coral trout (Section 3.4.5) from the Great Barrier Reef ecosystem are largely unknown but have the potential to alter food webs.[37]

Compliance with zoning arrangements, spawning closures, and quotas is a key contributor to the status of coral trout populations and their continued recovery in zones closed to fishing. Reports of non-compliance in the commercial line fishery have increased since 2004/05 (figure 4.15).

7.2.5 Loggerhead turtles

The eastern Australian loggerhead turtle nesting beaches, located along the Woongarra coast in south-east Queensland and the islands of the Capricorn Bunker Group and Swains region, support the only significant stock of this species in the South Pacific Ocean. The breeding population has declined by 70 to 90 per cent since the 1970s from an annual population of about 1000 females to less than 300. This, combined with their long maturation (age at first breeding is more than 20 years) and low reproductive rate (breeding every two to five years), means that the remaining loggerhead turtle population is at serious risk of local extinction from any increase in mortality or loss of nesting habitats.[38] Female turtles return to nest in the area where they hatched, so if the population did die out, it is highly unlikely that it would be readily recolonised by loggerhead turtles from another population elsewhere in the world.

Threats to loggerhead turtles include incidental capture in fishing gear, fox predation of mainland nests, incidental catch in shark control program gear (mostly drumlines), ingestion of marine debris, vessel strike, coastal development and increased incidence of disease.[38] Approximately 11 per cent of the foraging population in Moreton Bay, Queensland (south of the Great Barrier Reef Region) exhibited signs of anthropogenic impacts and/or health problems, with propeller cuts being the most frequently recorded.[39]

Management Loggerhead turtles are protected as a threatened species under Commonwealth, Great Barrier Reef and Queensland legislation. Management of loggerhead turtles within the Great Barrier Reef Region is through a combination of legislative requirements, operational policy and research addressing all known human-related pressures on loggerhead turtles. Management actions that have been specifically put in place to protect loggerhead turtles include:

- Identification of two key threatening processes under Commonwealth legislation (incidental catch of sea turtles during coastal otter-trawling and the ingestion of or entanglement in marine debris)
- The *Fisheries (East Coast Trawl) Management Plan 1999* required the mandatory use of turtle excluder devices
- A *Recovery Plan for Marine Turtles in Australia*
- Rezoning the Great Barrier Reef Marine Park increased the amount of loggerhead turtle habitat within highly protected zones[40]
- A summer trawl closure in the Woongarra Marine Park (south of the Great Barrier Reef Region) since 1991
- Baiting for foxes adjacent to nesting beaches in south-east Queensland
- 'Go slow' zones in Moreton Bay Marine Park, an important foraging area to the south of the Great Barrier Reef Region.

In addition, actions to address degraded water quality, such as *Reef Rescue Plan* and the *Reef Water Quality Protection Plan* and education campaigns to reduce litter entering the marine environment, should have flow-on benefits to loggerhead turtles.

Evidence for recovery The mandatory use of turtle excluder devices in the Queensland East Coast Otter Trawl Fishery was implemented in 2001. This has reduced the incidental capture and mortality of sub-adult and adult loggerhead turtles. With this major reduction in loggerhead turtle mortality, the nesting population increased over the next few years (figure 7.9) because more sub-adult turtles were able to become breeding adults and more adult turtles were able to complete their migrations to the nesting beaches.

Fox baiting programs implemented at mainland nesting beaches along the Bundaberg coast have positively influenced the success of loggerhead turtle nesting, by reducing the incidence of clutch destruction from 50 to 90 per cent in the 1970s and 1980s to nearly zero in 2003/04.[38]

However, the increase in the number of sub-adult and adult turtles may now be slowing due to declining recruitment of new immature loggerhead turtles into eastern Australian coastal waters over the last 15 years or more (Section 2.3.6). This decline may be due to incidental capture in international longline fisheries gear and the ingestion of marine debris. Also, expanding coastal development along the Woongarra coast has now resulted in more coastal lighting being visible to newly hatched turtles; this may significantly affect their ability to find the sea after hatching.[41]

In addition to direct threats to loggerhead turtles, climate change has the potential to affect nesting populations. Loss of nesting beaches from rising sea levels (Sections 3.2.5 and 5.2.1), altered sex ratios from increasing air temperatures (table 5.1) and projected changes in ocean circulation, storm intensity and the distribution of prey[42] (Section 5.2.1) will make recovery of the nesting population more difficult in the future.

Trawl turtle excluder devices have arrested the decline in loggerhead turtles but other pressures will influence their recovery.

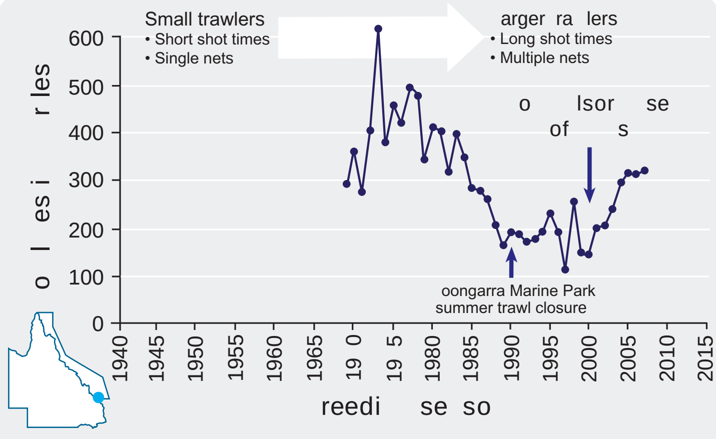
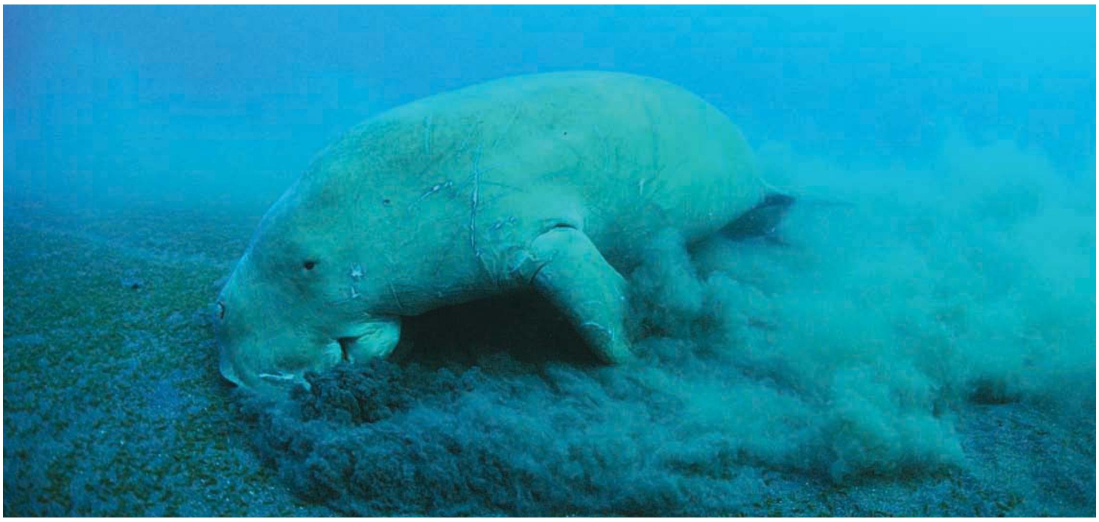


Figure 7.9 Decline and recovery in the nesting population of the east Australian loggerhead turtle[38]

Oral history indicates that the loggerhead nesting population was stable prior to the 1960s. Prior to the 1970s, trawl vessels were smaller than those used today, trawlers used single nets and kept them underwater for shorter periods of time. After the 1970s, increases in both the size of trawl vessels and the length of time the nets were deployed (shot time), and the use of multiple nets, contributed to decreases in the loggerhead turtle nesting population. Changes in management of coastal prawn trawl fisheries, including the introduction of turtle excluder devices (TEDs) appear to have resulted in an increase in the number of nesting turtles.



Dugong

7.2.6 Urban coast dugongs

Historical records suggest that dugongs occurred in very large numbers in Great Barrier Reef coastal waters prior to the mid-nineteenth century.[43] Today, the dugong population adjacent to the urban coast (defined as the area in the Great Barrier Reef from Cooktown south) is estimated to be less than 10 per cent of what it used to be.[44] Despite reductions in most sources of human pressure, dead dugongs continue to wash up on Queensland coasts and, of those where the cause of death has been determined, human activity is often implicated.[45]

The urban coast dugong population may take more than a century to recover and is subject to many continuing pressures.

The life history characteristics of dugongs are particularly relevant to conservation of the species. Dugongs are long-lived (over 70 years), slow to reach sexual maturity (females have their first calf at six to 17 years of age), and only calve once every two and a half to seven years.[46]

Management Dugongs are considered a threatened species within Queensland and are protected under Commonwealth, Great Barrier Reef and Queensland legislation. Management actions in response to declines in the dugong population along the urban coast of Queensland have partially addressed impacts associated with: incidental entanglement in large mesh (gill) nets in the Queensland East Coast Inshore Finfish Fishery and the Queensland Shark Control Program; Indigenous hunting; habitat degradation and declining water quality; vessel strikes; and the use of high explosives during defence activities. Relevant management actions have included:

- Establishment of 15 Dugong Protection Areas along the coast of the Great Barrier Reef (south of Mission Beach)
- A substantial increase in protection for key dugong habitats in the Great Barrier Reef Marine Park as a result of rezoning[47]
- A national partnership approach to assist Indigenous communities achieve sustainable harvests of dugongs
- Monitoring of dugong mortality along the Queensland coast as part of the Marine Wildlife Stranding Program
- Implementing voluntary vessel transit lanes in important dugong habitat in the Hinchinbrook area near Cardwell
- Protection of all seagrass under Queensland fisheries legislation and declaration of Fish Habitat Areas in some inshore seagrass habitats.

Evidence for recovery Based on population estimates in 2005 (figure 2.23), it appears that the dugong population is stable at the scale of the urban coast and has been for the past two decades.[48] However, it is not known whether this population will recover such that they can completely fulfil their ecological role as the largest herbivore on the Great Barrier Reef. Their very slow recovery is due in part to their very slow breeding rate and their extremely small population (less than 5000 individuals), and is exacerbated by the cumulative effects of continuing human impacts (e.g. incidental capture in fishing gear, poaching, ingestion of marine debris, boat strike, loss of seagrass foraging areas, traditional use of marine

Lionel Bevis is based in Yeppoon and has lived and worked throughout Queensland most of his life. He recollects his time in the 1950s working out of the **Tangalooma Whaling Station**.

> *"Then they [the Australian Whaling Commission] would determine a starting date which was usually about the first week in May because that's when the whales would start their migration. We'd go hell for leather then. Once you started whaling, you didn't stop until you had your quota… You don't have to be a mathematician to work it out, if you're knocking off a thousand a year – and that's exactly how it went, from 1952 to 1962… It was like going out and shooting the last elephant. Why would you if you knew, but we didn't. It was the times we lived in."*

resources). Even under optimum conditions, dugong populations can only increase at about five per cent per year.[46]

The recovery of dugongs along the urban coast will be influenced by the state of seagrass habitats (Sections 2.2.1 and 2.3.1), its principal food source. Inshore seagrass beds are particularly vulnerable to disturbance and loss due to coastal activities such as reclamation, dredging and other foreshore development, increased sedimentation and degraded water quality.[49] After serious disturbance, intertidal seagrasses normally recolonise areas within months to years.[50] This recovery depends on the availability of seed banks, water quality and the amount of sedimentation.

7.2.7 Humpback whales

When the hunting of humpback whales was banned in Australia in 1963, the eastern Australian population was less than five per cent of that estimated earlier in the century and they were seldom seen on the Great Barrier Reef. The prohibition on whaling addressed the single biggest factor in the decline of the humpback whale population.

Management Humpback whales are considered a species of conservation concern (Section 2.1.2) and are protected under Commonwealth, Great Barrier Reef and Queensland legislation. Today, human impacts on humpback whales include incidental catch in gear associated with fishing and the Queensland Shark Control Program, collisions with vessels and the potential effects of whale watching by recreational visitors and tourists. Their management within the Great Barrier Reef ecosystem is governed by a system of legislative requirements (e.g. regulations on how close vessels and aircraft can approach whales, a national recovery plan); operational policy (e.g. addressing tourism-related whale watching activities); national guidelines and best practices.

Evidence for recovery Humpback whales appear to be recovering steadily, with the population that migrates up the east coast of Australia each winter increasing at about 10 per cent per year[51] (figure 7.10). Numbers of humpback whales on the east Australian coast today are estimated to be about half their pre-whaling numbers and at current rates of increase could return to their earlier numbers within the next 20 years.

Humpback whales appear to be recovering at their maximum rate 45 years after whaling stopped.

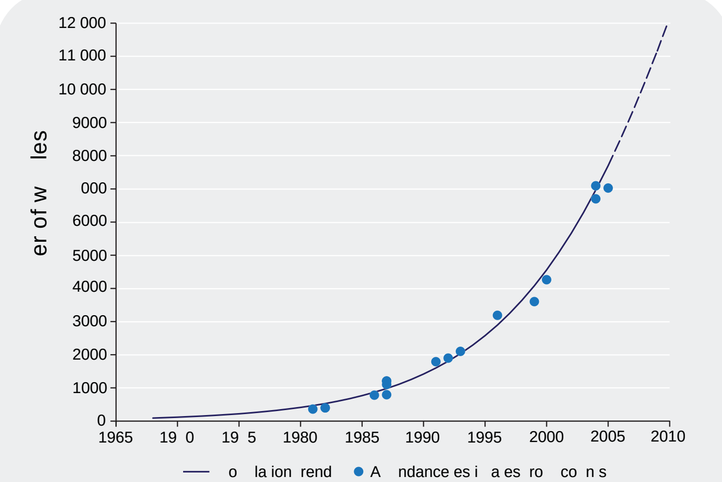


Figure 7.10 **Recovery of the eastern Australian humpback whale population since whaling ceased in the 1960s**

Humpback whales appear to be recovering steadily, with the population that migrates up the east coast of Australia each winter increasing at about 10 per cent per year. (The data to construct this graph was collated by Dave Paton (Centre for Cetacean Research and Conservation) and Dr Mike Noad (University of Queensland) using individual population estimates extracted from several sources[52 53 54 55 56 57 58 59])

7.3 Assessment summary – Ecosystem resilience

Section 54(3)(e) of the *Great Barrier Reef Marine Park Act 1975* requires *"…an assessment of the current resilience of the ecosystem …"* within the Great Barrier Reef Region. This overall assessment of ecosystem resilience is based on the information provided in earlier chapters of this Report, namely the current state and trends of the Great Barrier Reef ecosystem's biodiversity and health as well as the trends in direct use, the factors influencing future environmental values and the effectiveness of protection and management arrangements. It is supplemented by a series of case studies addressing:

- recovery after disturbance.

7.3.1 Recovery after disturbance

Assessment component	Summary	Assessment Grade: Very good	Good	Poor	Very poor
Coral reef habitats	Coral reef habitats are recovering from multiple short-term disturbances. Predicted increases in frequency and severity of disturbances will likely reduce the capacity for coral reefs to recover.		●		
Lagoon floor habitats	Some lagoon floor habitats previously at risk are recovering from disturbances. Full recovery will take decades.		●		
Black teatfish	Populations of black teatfish are low and are not recovering.				○
Coral trout	The number and size of coral trout is increasing rapidly in zones closed to fishing.		●		
Loggerhead turtles	Trawl turtle excluder devices have arrested the decline in loggerhead turtles but other pressures will influence their recovery.			○	
Urban coast dugongs	The urban coast dugong population may take more than a century to recover and is subject to many continuing pressures.				○
Humpback whales	Humpback whales appear to be recovering at their maximum population growth rate 45 years after whaling stopped.	●			
Recovery after disturbance	Some disturbed populations and habitats have demonstrated recovery after disturbance (for example coral reefs, lagoon floor, coral trout, humpback whales). For some species recovery has been very slow (for example loggerhead turtles) or not evident (black teatfish, dugongs) and is dependent on the removal of all major threats. Increasing frequency and extent of threats are likely to reduce the resilience of species and habitats.		◉		

GRADING STATEMENTS

Very good - Under current management, throughout the ecosystem, populations of affected species are recovering well, at rates close to their maximum reproductive capacity. Affected habitats are recovering within expected natural timeframes, following natural cycles of regeneration.

Good - Populations of affected species are recovering at rates below their maximum reproductive capacity. Recovery of affected habitats is slower than naturally expected but structure and function are ultimately restored within a reasonable timeframe.

Poor - Populations of affected species are recovering poorly, at rates well below their maximum reproductive capacity. Recovery of affected habitats is much slower than expected natural timeframes and the resultant habitat is substantially different.

Very poor - Affected species are failing to recover and affected habitats are failing to recover to their natural structure and function.

7.3.2 Overall summary of ecosystem resilience

At the scale of the Great Barrier Reef ecosystem, most habitats or species groups are in good condition; however there have been declines in species that play key ecological roles. These declines have been mainly due to direct use of the ecosystem, land management practices in the catchment, or declining environmental variables because of climate change.

There are concerns about aspects of the ecosystem's health. Sea temperature, sea level and sedimentation are all expected to increase because of climate change and catchment runoff, causing deterioration to the ecosystem. Changes in the chemical processes of ocean acidity, nutrient cycling and pesticides now affect large areas of the ecosystem. At the same time, reductions in some predator and herbivore populations may have already affected ecological processes, although the specific effects remain unknown. Outbreaks of diseases appear to be becoming more frequent and more serious.

The vulnerabilities of the ecosystem to climate change, coastal development, catchment runoff and some aspects of fishing mean that recovery of already depleted species and habitats requires the management of many factors. In some instances, the ecosystem's ability to recover from disturbances is already being compromised with either reduced population growth or no evidence of recovery.

The independent assessment of existing protection and management found that management is most challenging for those topics which are broad in scale (often well beyond the boundaries of the Great Barrier Reef) and complex. For example addressing climate change impacts requires global responses; coastal development and water quality require coordinated actions throughout the catchment. The management of fishing is socially and biophysically complex. The assessment indicated that addressing cumulative impacts is one of the least effective areas of management.

Notwithstanding these challenges, many of the management measures employed in the Great Barrier Reef Region and beyond are making positive contributions to resilience (as evidenced by recovery of some species and habitats). The Zoning Plans for both the Great Barrier Reef Marine Park and the adjacent Great Barrier Reef Coast Marine Park that were introduced in 2004 are the most significant action taken to enhance biodiversity protection. They provide a robust framework for management and are already demonstrating positive results. Compliance with and public support for these and other measures is a critical factor in building the resilience of the ecosystem.

Taken together, available information indicates that the overall resilience of the Great Barrier Reef ecosystem is being reduced. Given the effectiveness of existing protection and management in addressing the most significant pressures on the ecosystem (principally arising from outside the Region), this trend is expected to continue.

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RISKS TO THE REEF

CHAPTER EIGHT

"The pressures on its future remain heavy, but the counter pressures have proved stronger... Though its brilliant waters have been dulled and darkened here and there by unwise and greedy uses and human and industrial forms of pollution, the Great Barrier Reef is still the closest most people will come to Eden."

Judith Wright, 1996
Poet, author and advocate for the Great Barrier Reef

"an assessment of the risks to the ecosystem..." within the Great Barrier Reef Region, Section 54(3)(d) of the *Great Barrier Reef Marine Park Act 1975*

8 RISKS TO THE REEF

8.1 Background

Concerns for the Great Barrier Reef's health and wellbeing have highlighted many issues over the past 50 years. Outbreaks of crown-of-thorns starfish, the prospect of drilling for oil and the mining of reef limestone stirred widespread public concern in the 1960s. These threats were largely responsible for government initiatives to focus scientific effort on the Great Barrier Reef as well as to manage it proactively.

In the early 1980s, the priorities for managing the Great Barrier Reef were to address the identified risks arising from the absence of a planning regime, the lack of basic scientific knowledge to underpin management decisions and the lack of management. By the late 1990s, management directions were focused on the critical issues of conservation, water quality, coastal development, fisheries, tourism and recreation.

More recently, the potentially catastrophic risk of climate change was assessed[1] and became a focus of management in 2007.

This assessment addresses the risks that remain to the Great Barrier Reef after considering the effectiveness of existing measures to protect and manage the ecosystem.

8.2 Scoping and assessing current threats

8.2.1 Scoping current threats

Most stakeholders agree on the major threats to the Great Barrier Reef ecosystem.

In preparing this Outlook Report, opinions and issues regarding potential threats to the Great Barrier Reef ecosystem were gathered from a broad range of sources, including reef scientists, stakeholders, industry partners and the local community. Seventy coral reef scientists participated in an online survey to identify and rank threats. The Great Barrier Reef Marine Park Authority's 11 regionally based Local Marine Advisory Committees and four issues-based Reef Advisory Committees participated in a more detailed process to identify and rank threats to the ecosystem. Broader community views were gauged through an attitudinal survey.[2]

All groups expressed similar views on the most serious threats to the Great Barrier Reef ecosystem (table 8.1). Of primary concern were climate change, rural and agricultural development and catchment runoff, urban and industrial development and runoff, and fishing pressure.

The consultation processes with the Local Marine Advisory Committees and Reef Advisory Committees identified more than 400 individual issues; these were consolidated into a final set of 41 threats to the Great Barrier Reef ecosystem (Appendix 3), which are the basis of this assessment. These threats very closely reflect the factors identified in Chapter 5.

The threats that the committees identified relating to management resources and governance are broadly considered in Chapter 6.

8.2.2 Assessing threats

To assess the risks to the Great Barrier Reef ecosystem posed by the 41 threats, the Australian Standard for risk assessment (AS/NZS 4360:2004) was followed. The best available information about the current state of the ecosystem, current use patterns, factors that are influencing the ecosystem, effectiveness of management and current resilience of the ecosystem was used (see Chapters 2-7).

Both the likelihood and consequence of each predicted threat were ranked on a five-point scale (Appendix 4). An overall risk level for each threat was then determined, based on both its likelihood and consequence.

Table 8.1 Community views on the threats facing the Great Barrier Reef ecosystem

A range of groups were surveyed about their perceived threats to the Great Barrier Reef ecosystem. The ranking of these threats was purely on the priority of each risk to the Great Barrier Reef as identified collectively within each group. The responses were very similar, with climate change and rural and agricultural development and catchment runoff viewed as the most significant threats.

Community group	Ranking of perceived risk					
	First	Second	Third	Fourth	Fifth	Sixth
Queensland community	Climate change	Rural and agricultural development and catchment runoff	Fishing pressure	Urban and industrial development and runoff	Too many tourists	Introduction of exotic pests and diseases
Scientific community	Climate change	Rural and agricultural development and catchment runoff	Urban and industrial development and runoff	Fishing pressure	Governance and resources	Broad global and national issues
Local Marine Advisory Committees	Climate change	Rural and agricultural development and catchment runoff	Urban and industrial development and runoff	Governance and resources	Fishing pressure	Introduction of exotic pests and diseases
Reef Advisory Committees	Climate change	Governance and resources	Rural and agricultural development and catchment runoff	Community awareness	Fishing pressure	Boating and recreation

It is important to note that such a risk assessment can only include those threats to the ecosystem that are known and identified. There is likely to be more unknown and unanticipated threats that have not been considered. Hence, the list of threats considered in subsequent Outlook Reports may be different.

Comprehensive risk analysis of an ecosystem the size and complexity of the Great Barrier Reef (recognising that each of the many threats affect the system over different time scales, at different intensities and with widely variable synergistic relationships) would be an undertaking well beyond the scope of this Report. Thus, several important broad assumptions were made to facilitate the assessment provided here:

- Each threat was initially assessed in isolation from others; compounding effects are discussed separately (Section 8.3.4)
- Each threat was assumed to be possible at any geographic location
- Threats were assessed as they are today (for example, current fishing catch amounts and techniques) or on the basis of documented trends (for example, trends in sea temperature and ocean acidification)
- Threats were assessed with existing, but not any future, management measures in place.

It is important that the results below are interpreted with these assumptions in mind.

8.3 Overall threat to the ecosystem

8.3.1 Most serious threats

The results of the formal risk assessment closely correspond with conclusions presented in earlier chapters of this Report. Based on the outcomes of the risk assessment (figure 8.1), six of the 41 identified threats are a very high risk to the Great Barrier Reef ecosystem and another nine threats are a high risk. A better understanding of the individual threats is gained by linking each of the threats to the factors influencing the Reef's values identified in Chapter 5 (figure 8.2).

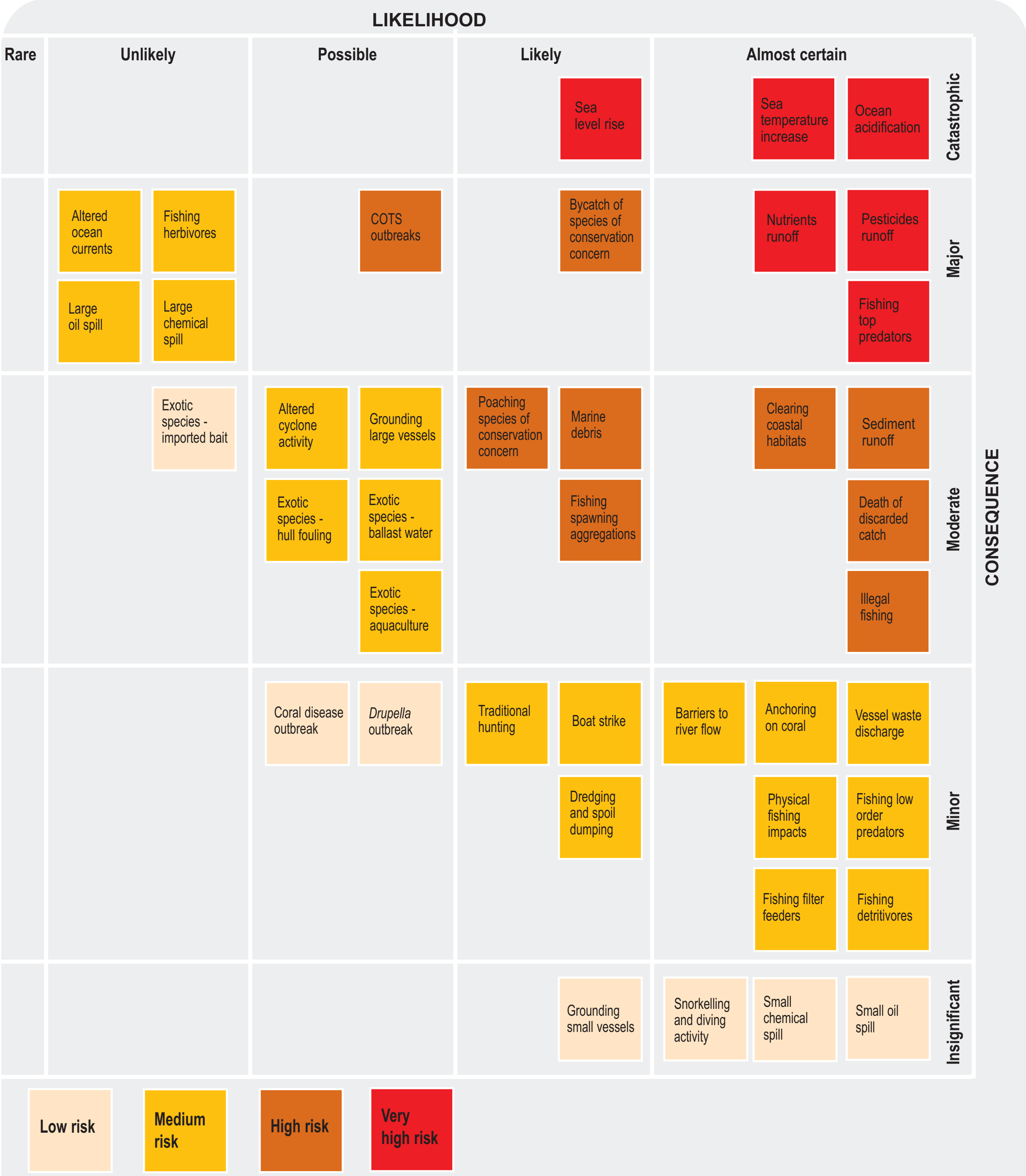

Figure 8.1 Current risks to Great Barrier Reef ecosystem

This risk matrix has been developed in accordance with the Australian Standard (AS/NZS 4360:2004) using terms and definitions detailed in Appendix 4. The assessment is based on current or documented trends in the identified threats and existing management measures. The compounding effects of threats are not considered. The full wording for each of the identified threats is provided in Appendix 3.

The greatest threats to the Great Barrier Reef ecosystem, as identified by the risk assessment (figure 8.1) are:

- **Climate change:** increasing sea temperature, ocean acidification and rising sea level
- **Catchment runoff:** nutrients, pesticides (including herbicides) and sediments entering the Great Barrier Reef
- **Coastal development:** clearing or modifying wetlands, mangroves and other coastal habitats and ingestion of or entanglement in marine debris causing death in species of conservation concern.
- **Direct use – extractive:** extraction of top predators by fishing (e.g. sharks), incidental catch during fishing of species of conservation concern, illegal fishing or collecting (foreign or domestic), death of discarded species during fishing or collecting, fishing in unprotected fish spawning aggregations and poaching (illegal hunting) of species of conservation concern.

The threats associated with direct use of the Great Barrier Reef Region that do not involve extraction of its resources are generally of lower risk to the ecosystem. For example the threats of large oil and chemical spills, grounding of large vessels and anchoring on coral by small vessels are assessed as medium risk. Large oil and chemical spills are considered unlikely to occur because of the management arrangements in place, but could have major consequences on the ecosystem. Threats such as physical impacts of snorkelling and diving activity, small oil and chemical spills, and grounding of small vessels are low risk.

Some threats are driven by more than one factor. For example, the high risk of ingestion of or entanglement in marine debris causing death in species of conservation concern, is affected by coastal development (e.g. the use of plastic bags) and also influenced by direct extractive and non-extractive use of the Great Barrier Reef (e.g. littering whilst at sea).

On a positive note, several threats previously considered high risk are now assessed as low risk due to effective management arrangements (Chapter 6). For example, the physical impacts of fishing are now a medium risk because of the management arrangements for trawling (Section 7.2.2). The risk of damage to corals and other organisms from anchoring, vessel groundings and diving and snorkelling activities has been reduced by improved management of tourism activities, site management and education.

In addition, a management focus on the threats associated with land-based aquaculture beginning earlier this decade has lowered the risks of this activity in the Great Barrier Reef catchment.

Threat-focussed management measures are significantly reducing the risk to the Great Barrier Reef ecosystem from land-based aquaculture such as this prawn farm near the mouth of the Burdekin River.

Climate change, coastal development, catchment runoff and extractive use are the most serious risks to the Great Barrier Reef ecosystem.

Marine tourism - reducing risks and driving conservation

In the early 1980s, tourism numbers to the Great Barrier Reef were increasing by about 30 per cent annually.[3] From this time to the early 1990s, tourism was perceived by some as a risk to the very values that make the Great Barrier Reef an iconic destination.

The Great Barrier Reef Marine Park Authority responded to the potential risks of this increasing activity with limits to the number of tourism craft in high use areas; vessel and group size limits; site management arrangements; regulations; and operational policy (such as for moorings, bareboats (self-sail) and cruise ships). Over the last decade, the tourism industry has worked to achieve high standards and make a contribution to management. A clearly articulated common goal of a healthy reef and a healthy industry is now shared by the Great Barrier Reef Marine Park Authority and the tourism industry.

Tourism numbers have been stable since the mid-1990s and the footprint of marine tourism on the Great Barrier Reef is considered to be small and generally localised.[4] Threats to the Great Barrier Reef ecosystem that could be associated with tourism activities, such as anchoring on coral, physical damage of snorkelling and diving and grounding of small vessels have been significantly reduced and are now considered to be generally low risk to the ecosystem (figure 8.1).

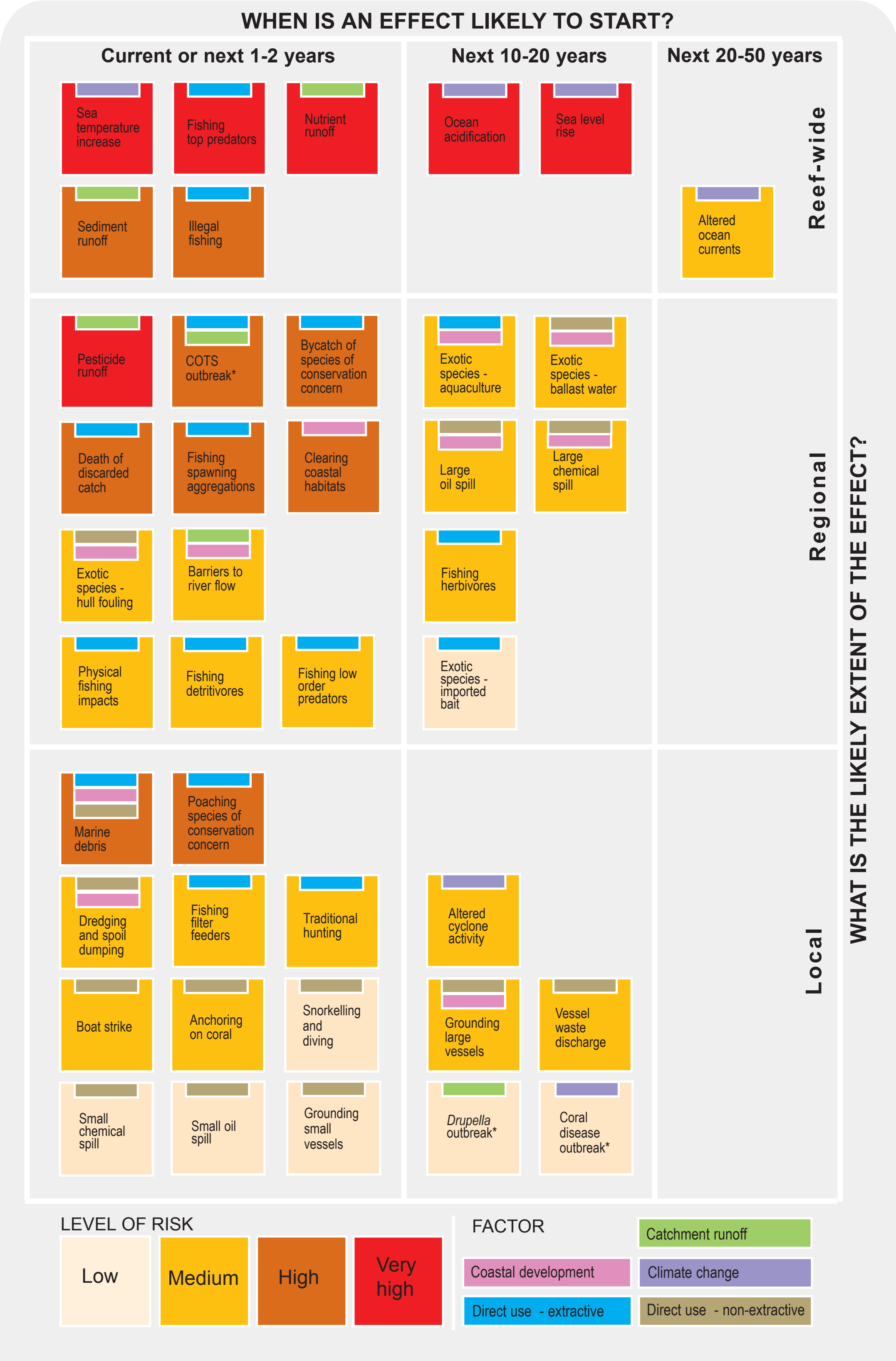

Figure 8.2 Extent and timing of threats and their driving factors

Climate change and catchment runoff are driving most of the very high risk threats to the ecosystem. Most of the threats that present a very high risk to the Great Barrier Reef ecosystem are already having an effect (left hand column) or are expected to in the next 10-20 years (middle column). In addition, the threats assessed as very high risk are expected to have an effect Reef-wide (top row). Those threats for which the factors are not clearly known are marked with an asterisk (*).

Reducing the risks of land-based aquaculture

Potential threats associated with land-based aquaculture adjacent to the Great Barrier Reef Marine Park include nutrients and sediments from catchment runoff, clearing or modifying coastal habitats and the introduction of exotic pests and diseases.

Since the introduction of the *Great Barrier Reef Marine Park (Aquaculture) Regulations 2000*, there has been a significant improvement in the environmental performance of land-based aquaculture facilities. These Regulations directly regulate land-based pollutant inputs to the Marine Park. At the same time, collaboration between the Australian and Queensland Governments and industry has led to the development of operational policies that articulate minimum standards for environmental sustainability.

8.3.2 Scale and timing of threats

The identified threats to the Great Barrier Reef are highly variable in both timeframe and the scale of impact (figure 8.2). Some of the threats identified as highest risk are impacting the ecosystem at a Reef-wide scale and are happening now (for example, the very high risk threats of sea temperature increase and nutrients from catchment runoff). Significantly, a majority of the threats considered in this assessment are already affecting the ecosystem or are likely to do so in the next few years. Of the very high risk threats, ocean acidification and sea level rise are predicted to show major impacts over a longer time frame (within 10 to 20 years, refer Section 5.2), although their effects are already beginning to be documented.

Ultimately, the extent and timing of many of these threats will be determined by overarching drivers of change such as global concentrations of greenhouse gases, population growth (both in the catchment and globally) and global economic conditions. These drivers are well beyond the management control of agencies responsible for protecting and managing the Great Barrier Reef ecosystem.

Community attitude is an important catalyst for change. In a 2007 survey, members of communities along the Great Barrier Reef coast and in Brisbane, Sydney and Melbourne overwhelmingly considered that the general community had a role to play in looking after the Great Barrier Reef (97 per cent for coastal areas and 91 per cent for southern capitals).[5]

8.3.3 Origin and existing management of threats

The effectiveness of existing protection and management is outlined in Chapter 6. For the factors of climate change (Section 6.2.2), catchment runoff (Section 6.2.12) and coastal development (Section 6.2.3), the origins of the threats are outside the Great Barrier Reef Region (either global or within the Great Barrier Reef catchment). Management of these factors was independently assessed as some of the weakest of all the management topics considered, especially in terms of outcomes (figure 8.3).

The threats associated with extractive use (such as from fishing, some traditional use, some scientific research) originate from within the Great Barrier Reef Region. Like the other high risk factors; existing management of these factors was independently assessed as amongst the weakest, especially in terms of outcomes (for fishing) and financial, staffing and information inputs (for fishing and traditional use). Direct use of the Great Barrier Reef Region that is not extractive (i.e. commercial marine tourism, defence activities, shipping, recreation (not including fishing), some scientific research and some traditional use) is generally more effectively managed and is assessed as a lower risk to the ecosystem.

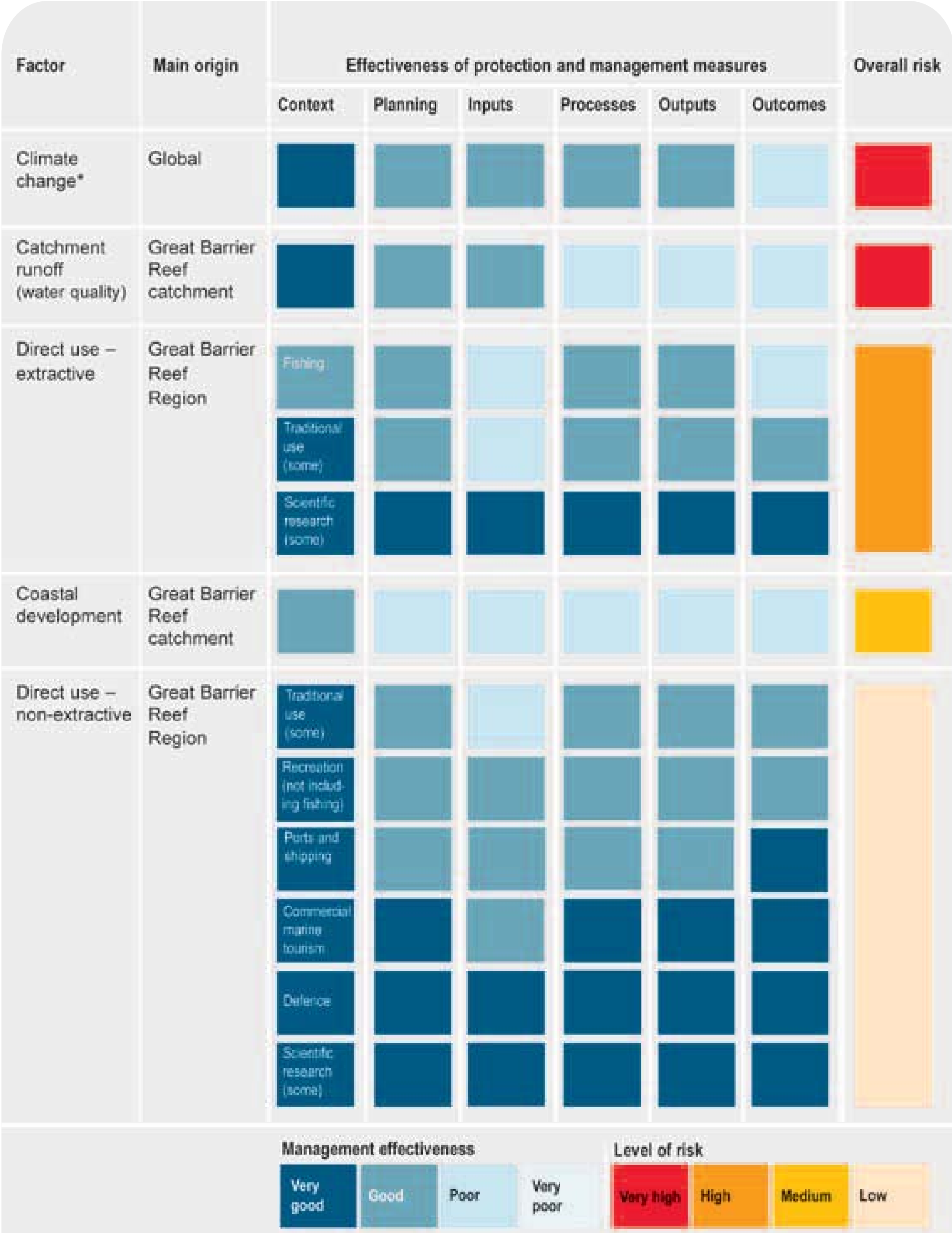

Figure 8.3 Effectiveness of existing management for identified risk factors

Except for direct extractive use of the ecosystem, the factors that present the highest overall risk to the Great Barrier Reef ecosystem have their origins outside the Great Barrier Reef Region. The effectiveness of management for the four highest risk factors are some of the weakest of the management topics assessed in an independent assessment (based on the six elements: understanding of context; planning; financial, staffing and information inputs; management systems and processes; delivery of outputs and achievement of outcomes). Refer to Chapter 6 for a full discussion of the effectiveness of existing management. (*) The assessment of management effectiveness for the topic of climate change is only in relation to management measures undertaken specifically to protect and manage the Great Barrier Reef.

Big-eyed trevally

8.3.4 Interactions and compounding effects

None of the threats to the Great Barrier Reef ecosystem operate in isolation from one another. Each is present at the same time and affecting the same ecosystem. As a result, the Great Barrier Reef's natural values are under severe pressure and the ecosystem's resilience to each threat is significantly compromised by the presence of other threats.

Many of the threats also have a synergistic effect, where the impact of two or more threats acting together is much worse than that expected from the sum of their individual impacts. Although the detail of such compounding effects is beyond the scope of this Report, they are likely to dominate much of the future outlook for the Great Barrier Reef (Chapter 9). For example, a coral's ability to recover from bleaching resulting from a rise in sea temperature is much reduced if it is living in degraded water where ecological processes have been compromised.[6]

The risk presented by each individual threat is compounded and sometimes magnified by the other threats.

Each of the above conditions will be exacerbated further by predicted effects of climate change: more frequent events (mass bleaching, severe cyclones and runoff), compromised growth rates or skeletal strength (ocean acidification) and disease outbreaks. Even small changes in a range of key physical, chemical or ecological processes may result in sudden widespread deteriorations on a scale not observed previously - which would in turn reduce even further the resilience of the ecosystem.

8.4 Assessment summary – Risks to the Reef

Section 54(3)(d) of the *Great Barrier Reef Marine Park Act 1975* requires *"…an assessment of the risks to the ecosystem…"* within the Great Barrier Reef Region. This assessment is based on the current state and trends of the Great Barrier Reef ecosystem's biodiversity and health, the factors influencing the values of the Region, the effectiveness of protection and management arrangements and ultimately an understanding of the ecosystem's overall resilience.

8.4.1 Overall threat to the ecosystem

Assessment components	Summary	Assessment Grade: Low risk	Medium risk	High risk	Very high risk
Climate change	The threats of increasing sea temperature, ocean acidification and sea level rise are very high risks to the ecosystem.				○
Catchment runoff	The threats of nutrients, pesticides and sediments from catchment runoff are high and very high risks to the ecosystem.			○	
Coastal development	Clearing of coastal habitats is a high risk to the ecosystem, as is the threat of ingestion of marine debris by species of conservation concern.			○	
Direct use – extractive	There are a number of threats associated with fishing and traditional use. Extraction of top predators is a very high risk to the ecosystem, others are of either high (such as illegal fishing) or medium risk.			○	
Direct use – non-extractive	There are a number of threats from non-extractive use, generally of low to medium risk. Large chemical and oil spills, although unlikely, could be of major consequence.		○		
Overall threat to ecosystem	The ecosystem is at serious risk from the compounding impacts of climate change, catchment runoff, coastal development and extractive use. Of the many other threats to the Great Barrier Reef ecosystem, most present a small risk individually, but combine to further reduce ecosystem resilience. Other threats are effectively managed and are now assessed as a much reduced risk.			○	

GRADING STATEMENTS

Low risk - Given current management arrangements, any threats considered likely or certain to occur are predicted to have no more than insignificant consequences for the ecosystem. There may be minor or moderate consequences for the Region's ecosystem for other less likely threats.

Medium risk - Given current management arrangements, few of the threats considered likely or certain to occur are predicted to have moderate consequences for the Region's ecosystem and none will have catastrophic consequences. Some unlikely threats may have major consequences for the Region's ecosystem.

High risk - Given current management arrangements, many of the likely or almost certain threats are predicted to have moderate or major consequences for the Region's ecosystem.

Very high risk - Given current management arrangements, there are likely or almost certain threats that are predicted to have catastrophic consequences on the Region's ecosystem.

8.4.2 Overall summary of risks to the Reef

This risk assessment combines the knowledge presented in earlier chapters of the Report to provide an assessment of current and potential threats to the Great Barrier Reef and is an important step in predicting the future of the ecosystem.

The greatest threats facing the Great Barrier Reef ecosystem are from climate change. The individual threats of increasing sea temperature, ocean acidification and rising sea level are assessed as very high risk to the ecosystem and they will act across the entire Region. Their impact will be compounded by each other and by other existing regional and local threats.

The most serious, regional-scale risks are catchment runoff, coastal development and some aspects of extractive use. These threats have the potential to work in combination to weaken the resilience of the Great Barrier Reef and therefore its ability to recover from serious disturbances (such as major coral bleaching events) that will become more frequent in the future.

While climate change will affect all parts of the Great Barrier Reef, the compounding effects of threats associated of catchment runoff, coastal development and some extractive use means that the nearshore environment next to developed areas is the most at risk.

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LONG-TERM OUTLOOK

CHAPTER NINE

"We must ... keep hope for the future alive. There may come a time during this century when most reefs the world over will look like the worst of them do today – so degraded that people who remember what a healthy reef looks like might come to feel that reefs are no longer worth bothering with. Whatever the future holds, we must never entertain such thoughts about the greatest marine World Heritage region on Earth."

J.E.N. Veron, 2008
Leading reef scientist and author

"an assessment of the long-term outlook for the ecosystem…" within the Great Barrier Reef Region, Section 54(3)(h) of the *Great Barrier Reef Marine Park Act 1975*

9 LONG-TERM OUTLOOK

9.1 Background

The Great Barrier Reef contains 10 per cent of all the world's coral reefs and is internationally recognised as a World Heritage Area. It is comparatively healthier than most coral reef ecosystems around the world. However, the condition of the Great Barrier Reef has declined significantly compared to its condition prior to European settlement and, as a result, the overall resilience of the ecosystem has been reduced, in turn reducing its ability to recover from future disturbances.

Predicting a long-term outlook for the Great Barrier Reef ecosystem is a difficult and complex task. In developing this outlook, consideration has been given to the current state and trends of the Great Barrier Reef's environmental, economic and social values (Chapters 2, 3 and 4), the factors affecting those values (Chapter 5), the effectiveness of protection and management measures (Chapter 6), the resultant resilience of the ecosystem (Chapter 7) and, finally, the risks the ecosystem is facing (Chapter 8). While no future developments in the management of the threats to the ecosystem have been anticipated, relevant management initiatives that have been identified but not yet fully implemented are taken into consideration.

9.2 Likely trends in key factors

Factors external to the Great Barrier Reef are playing an increasing role in determining its future condition. Climate change, coastal development and catchment runoff are three key factors affecting the long-term outlook for the Great Barrier Reef ecosystem. These factors operate at large geographic scales (globally for climate change) and are socially, biophysically and jurisdictionally complex. Direct extractive use, such as fishing and traditional use, which is more localised, is also a key factor in the future of the ecosystem. The future of the Great Barrier Reef will be largely determined by the cumulative and collective impacts of and trends in these four factors, as well as the management responses to these trends.

9.2.1 Climate change

Coral reefs are one of the world's ecosystems that are most vulnerable to climate change[1], and the Great Barrier Reef is no exception. Climate change factors are likely to have the greatest influence on the long-term outlook for the Great Barrier Reef. It is predicted that the progress of degradation will not be linear, rather ecological responses to climate change will likely occur in a series of abrupt steps separated by intervals of relatively minor change.

Specific climate change threats that present a high risk to the Great Barrier Reef ecosystem are:

- **Increasing sea temperature** As sea temperatures increase, the Great Barrier Reef is becoming increasingly exposed to the possibility of a catastrophic mass bleaching event. In the last century, the average sea surface temperature of the Great Barrier Reef has increased by 0.4ºC. Rising global temperatures mean that unusually warm local weather conditions are much more likely to increase water temperatures above bleaching thresholds.
- **Increasing ocean acidification** In the last century, the pH of the ocean has decreased by 0.1 units (i.e. become more acidic). Recent studies on the Great Barrier Reef suggest that coral growth is already being affected.[2]
- **Rising sea level** The sea level in the Great Barrier Reef Region has already risen by about 3mm annually since 1991. Sea level rise is a threat to islands and cays that are important for nesting seabirds and marine turtles. It is also important in the context of coastal infrastructure and low lying urban centres.

Prediction for the Great Barrier Reef

'If atmospheric carbon dioxide levels stabilise at 420ppm and the sea temperatures of the Great Barrier Reef increase by 0.55°C, mass bleaching events will be twice as common as they are at present.

If atmospheric carbon dioxide concentrations increase beyond 450ppm, together with a global temperature rise of 1°C, a major decline in reef-building corals is expected. Under these conditions, reef-building corals would be unable to keep pace with the rate of physical and biological erosion, and coral reefs would slowly shift towards non-carbonate reef ecosystems. Reef ecosystems at this point would resemble a mixed assemblage of fleshy seaweed, soft corals and other non-calcifying organisms, with reef-building corals being much less abundant, even rare. As a result, the three-dimensional structure of coral reefs would slowly crumble and disappear.

Depending on the influence of other factors such as the intensity of storms, this process may happen either slowly or rapidly…

A carbon dioxide concentration of 500ppm or beyond, and likely associated temperature change, would be catastrophic for the majority of coral reefs across the planet. Under these conditions the three-dimensional structure of the Great Barrier Reef would be expected to deteriorate and would no longer be dominated by corals or many of the organisms that we recognise today.'

Garnaut Climate Change Review, 2008[3]

9.2.2 Catchment runoff

The Great Barrier Reef, especially much of its inshore area, is being affected by increased sediments, nutrients and pesticides in catchment runoff mainly from diffuse agricultural sources. With recent advances in agricultural practices and additional government programs, there has been a reduction in sediment and nutrient inputs into some coastal river systems, but a long lag time is expected before there are positive effects on marine water quality.

The effects of degraded water quality on the Great Barrier Reef include the reduction of hard coral cover at some inshore reefs; the increase of diseases and crown-of-thorns starfish outbreaks; the incorporation of pesticides into tissues of invertebrates, marine turtles and marine mammals; and a reduced ability for coral reefs to recover from bleaching or crown-of-thorns starfish outbreaks. Recent flooding from the Great Barrier Reef catchment has resulted in elevated nutrient concentrations in river plumes reaching mid-shelf reefs.

Scientific consensus on water quality in the Great Barrier Reef (GBR)

An analysis of the latest available evidence concludes:

'1. Water discharged from rivers to the GBR continues to be of poor quality in many locations.
2. Land derived contaminants, including suspended sediments, nutrients and pesticides are present in the GBR at concentrations likely to cause environmental harm.
3. There is strengthened evidence of the causal relationship between water quality and coastal and marine ecosystem health.
4. The health of freshwater ecosystems is impaired by agricultural land use, hydrological change, riparian degradation and weed infestation.
5. Current management interventions are not effectively solving the problem.
6. Climate change and major land use change will have confounding influences on GBR health.
7. Effective science coordination to collate, synthesise and integrate disparate knowledge across disciplines is urgently needed.'

Scientific consensus on water quality in the Great Barrier Reef, 2008[4]

9.2.3 Coastal development

Coastal development, primarily driven by rural land use, mining and industry, population growth, urban infrastructure and port development, significantly affects the Great Barrier Reef. The highest risk threats associated with coastal development are clearing or modifying wetlands, mangroves and other coastal habitats and litter, such as plastic bags, washing out to sea and being ingested by species of conservation concern.

A main factor driving habitat loss is the increasing human population in the Great Barrier Reef catchments. Current projections estimate that a human population of nearly 1.5 million people will reside in the Great Barrier Reef catchment by 2026, a 40 per cent increase from the current population. Without adequate planning and careful environmental management, this growth could increase pollution and sedimentation, decrease water quality and change the natural drainage channels. The growth in human population is likely to substantially increase use of the Great Barrier Reef, particularly in areas close to population centres.

9.2.4 Direct use - extractive

The aspects of extractive use highlighted as being of highest risk to the Great Barrier Reef ecosystem relate to altered ecological processes contributing to ecosystem health. Fishing in the Great Barrier Reef targets mainly predators and particle feeders. Unless carefully managed at sustainable levels, the extraction of top predators can affect the ecological balance within the food web.

The lack of information about some target species, the fate of non-retained catch and the incidental catch of species of conservation concern means that the ecosystem level impacts of fishing are not well understood. Progress towards application of best practice management across all fisheries is being made, but not rapidly. For example, the compulsory use of turtle excluder devices in prawn trawl nets seems to have helped stop the decline of loggerhead turtles.

Illegal fishing pressure, by foreign or domestic fishers, can work against management arrangements to protect the ecosystem. Changes in global fisheries production patterns are likely to increase demand for wild caught seafood. On the Great Barrier Reef, the changes are likely to drive a diversification in the species targeted and the areas fished (including remote and deeper water) and increase the likelihood of illegal fishing.

Many Traditional Owner groups along the urban coast have recognised the decline in dugongs in that area and have voluntarily suspended their cultural harvest of this species. However, the lack of information about the levels of traditional hunting of threatened species like dugongs and green turtles creates uncertainty about the sustainability of the activity. In addition, many Traditional Owners have expressed concern about the illegal harvest (poaching) of these species in their sea country by non-Traditional Owners. As with most illegal activities, quantifying the numbers of threatened species which are illegally hunted is difficult.

Lower risk extractive activities, such as the targeting of lower order predators (e.g. coral trout), filter feeders (e.g. scallops) and detritivores (e.g. prawns and sea cucumbers) and the physical impacts of fishing continue to pose some threats to the ecosystem; however for the most part, the current management arrangements for those activities appear to be effective.

9.2.5 Direct use – non-extractive

Direct use of the Great Barrier Reef Region that is non-extractive (such as commercial marine tourism, shipping, some scientific research and recreation not including fishing) poses some threats to the ecosystem but none are considered to be high or very high risk. However, increasing regional populations and economic development may mean an increase in use of the Region, especially from recreation and shipping, and therefore the potential for greater impact to the ecosystem.

9.3 Current initiatives to improve resilience

The Great Barrier Reef Marine Park is considered by many around the world as a leading example of world's best practice management.[5 6 7] Building on these existing arrangements, several major management initiatives are underway to further address the key threats to the Great Barrier Reef ecosystem. These actions and the degree to which they are effectively implemented will strongly influence the Great Barrier Reef's resilience in the future.

Zoning Considered the most significant recent action taken to enhance biodiversity protection[8 9], the *Great Barrier Reef Marine Park Zoning Plan 2003* is having a positive influence on the ecosystem's biodiversity. However it only addresses ecosystem protection at a broad level. The continued effectiveness of the Zoning Plan relies in part on the continued enforcement of zoning arrangements and ensuring reef users are aware of the Plan and its provisions.

Reef Plan Introduced in 2003, the *Reef Water Quality Protection Plan* (Reef Plan) is a joint Australian and Queensland Government plan that aims to halt and reverse the decline in water quality entering the Great Barrier Reef by 2013. It is currently being updated and is supported by a range of initiatives, including the Australian Government's $200 million *Reef Rescue* initiative under the Caring for our Country Program, as well as proposed new Queensland Government regulations that will phase out unacceptable land practices in high risk Great Barrier Reef catchments. Effective implementation of actions under Reef Plan will contribute to improvement in water quality; however, these improvements are likely to take many years to be translated into measurable changes in ecosystem function.

Coastal planning and development To ensure that Queensland's system for planning and development is responsive to its rapidly changing needs, the Queensland Government has implemented a planning reform initiative *Planning for a Prosperous Queensland - A reform agenda for planning and development in the Smart State*. The reform is the culmination of an extensive review of planning and development in Queensland, including the *Integrated Planning Act 1997* and the Integrated Development Assessment System. The Act provides a framework for coordinating and integrating planning at the regional level with the aim of ecological sustainability. A critical part of the reform will be new and improved planning legislation planned to become operational in 2009.

Regional planning plays a key role in helping Queensland communities meet the challenges associated with rapid economic growth, population change and the increasing demand for public services at a local level. In late 2006, the Queensland Government commenced implementing a strategy to accelerate regional planning in regional and rural Queensland, following a three point plan:

- developing and implementing a consistent and contemporary framework for effective regional planning across Queensland
- accelerating implementation of the existing regional plans
- delivering regional plans in rural Queensland.

The vast majority of Queensland's populated coast will have commenced statutory regional planning processes through the accelerated regional planning program in 2009. The *Far North Queensland Regional Plan 2009-2031* was launched in early 2009 and is the over-arching plan for that region.

East Coast Inshore Finfish Fishery In 2008, the Queensland Government committed to implementing revised management arrangements for the East Coast Inshore Finfish Fishery. Recreational fishing measures were established to better manage the potential increasing fishing pressure resulting from population growth in coastal Queensland. This population growth has already resulted in an increase in the number of boats owned in the Great Barrier Reef catchment, which, combined with improvements in fishing technology, may put greater pressure on fisheries resources. The management arrangements also focus on the commercial large mesh (gill) net fishery. Proposed measures include a cap on the amount of shark that can be retained and changes to the way netting operates in order to reduce the incidental capture of species of conservation concern (e.g. speartooth sharks and dugongs).

Indigenous partnerships As part of the *Reef Rescue Plan*, $10 million has been allocated to the development of land and sea country Indigenous partnerships. This program aims to strengthen communications between local communities, managers and stakeholders; build a better understanding of Traditional Owner issues relating to the management of the Great Barrier Reef; and improve the sustainability of the traditional use of marine resources, especially where it is focused on species of conservation concern.

Climate change actions The focus of the *Great Barrier Reef Climate Change Action Plan, 2007-2012* is to increase knowledge about the implications of climate change for both the Great Barrier Reef and the people who depend upon it, and to develop and support strategies to foster adaptation and minimise impacts through improving and maintaining resilience. The Action Plan includes an objective to reduce climate footprints, particularly at a local level. It does not include any global mitigation actions. Other dedicated climate change programs are being implemented throughout the Great Barrier Reef Region and beyond by the Australian and Queensland Governments.

9.4 Assessment summary – Long-term outlook

Section 54(3)(h) of the *Great Barrier Reef Marine Park Act 1975* requires *"...an assessment of the long-term outlook for the ecosystem..."* within the Great Barrier Reef Region. This assessment is the culmination of all the previous assessments, particularly the assessments of current ecosystem resilience and the risks to the ecosystem.

9.4.1 Outlook for the Great Barrier Reef ecosystem

Assessment component	Summary	Assessment Grade: Very good	Good	Poor	Very poor
Outlook for the Great Barrier Reef ecosystem	Despite the introduction of significant protection and management initiatives, the overall outlook for the Great Barrier Reef is poor. Even with the recent initiatives to improve resilience, catastrophic damage to the Great Barrier Reef ecosystem may not be averted. Building the resilience of the Great Barrier Reef ecosystem will give it the best chance of adapting to and recovering from the serious threats ahead, especially from climate change. Given the strong management of the Great Barrier Reef, it is likely that the ecosystem will survive better than most other reef ecosystems around the world.			○	

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Very good - The Region's ecosystem is likely to remain healthy and resilient for the foreseeable future with strong recovery in threatened species and at damaged locations. Additional management intervention is not required to maintain the ecosystem.

Good - With only minor additional management intervention, the Region's ecosystem is likely to remain generally healthy and resilient for the foreseeable future, with only some areas showing signs of significant deterioration.

Poor - Without significant additional management intervention, some components of the ecosystem will deteriorate in the next 20 years and only a few areas are likely to be healthy and resilient in 50 years.

Very poor - Without massive additional management intervention, the Region's ecosystem is likely to deteriorate rapidly with the loss of most habitats and species over the next 50 years.

9.4.2 Overall summary for long-term outlook

The outlook for the Great Barrier Reef ecosystem, along with most other coral reef ecosystems, is at a crossroad, and it is decisions made in the next few years that are likely to determine its long-term future. Unavoidably, future predictions of climate change dominate most aspects of the Great Barrier Reef's outlook over the next few decades. The extent and persistence of the damage will depend to a large degree on the extent to which climate change is addressed worldwide and on the resilience of the ecosystem in the immediate future.

Many ecosystem components are already showing some effects from climate change (for example increased frequency and severity of coral bleaching and decreased density of coral structures).

It is only with atmospheric concentrations of carbon dioxide between current levels and about 400ppm that the key groups of species and habitats of the Great Barrier Reef have low or moderate vulnerability to climate change. If the atmospheric concentration of carbon dioxide increases beyond these levels then there will be serious consequences for the Great Barrier Reef. At a concentration of 500ppm, it is predicted that many components of the Great Barrier Reef ecosystem would be highly vulnerable, including seabirds, fish, marine reptiles and plankton. At about this concentration of carbon dioxide, hard corals would likely become functionally extinct and coral reefs would be eroding rapidly.

Much is being done to reduce the local and regional pressures on the Great Barrier Reef and therefore improve its resilience, for example improvements in land management practices and careful management of use of the Region. Management initiatives that further improve the resilience of the Great Barrier Reef ecosystem will mean that the ecosystem is better able to cope with and recover from the impacts of climate change in coming years. This resilience will depend in large part on how effectively the risks of coastal development, catchment runoff and some extractive use are addressed into the future.

Variations in ecosystem response to the threats will occur along the length and width of the Great Barrier Reef. Such regional differences are now observable and are likely to become more obvious over time. Generally, the areas at most significant risk are those closest to already developed areas that have already deteriorated more because of catchment runoff and coastal development. For some of the threats related to climate change, southern areas of the Great Barrier Reef Region, especially inshore, are predicted to be the most vulnerable.

Ultimately, if changes to the world's climate become too severe, no management actions will be able to climate-proof the Great Barrier Reef ecosystem.

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As descendants, we have a lifelong spiritual and physical connection to the land and sea - every living thing is connected through the circle of life. We have a lifelong responsibility to our ancestors to care for land and sea country.

Woppaburra Aspirational Statement
as part of the Woppaburra Traditional Use of Marine Resource Agreement

Statutory requirements for the Outlook Report

APPENDIX 1

54 Great Barrier Reef Outlook Report

(1) The Authority must prepare and give to the Minister a report in relation to the Great Barrier Reef Region every 5 years. The first report must be given to the Minister by 30 June 2009.

(2) The report must be prepared in accordance with the regulations (if any).

Content of report

(3) The report must contain the following matters:

(a) an assessment of the current health of the ecosystem within the Great Barrier Reef Region and of the ecosystem outside that region to the extent it affects that region;
(b) an assessment of the current biodiversity within that region;
(c) an assessment of the commercial and non commercial use of that region;
(d) an assessment of the risks to the ecosystem within that region;
(e) an assessment of the current resilience of the ecosystem within that region;
(f) an assessment of the existing measures to protect and manage the ecosystem within that region;
(g) an assessment of the factors influencing the current and projected future environmental, economic and social values of that region;
(h) an assessment of the long term outlook for the ecosystem within that region;
(i) any other matter prescribed by the regulations for the purposes of this paragraph.

Peer-review

(4) The Minister must arrange for the content of the report to be peer reviewed by at least 3 persons who, in the Minister's opinion, possess appropriate qualifications to undertake the peer review. The peer review must occur before the report is given to the Minister.

Report to be tabled in Parliament

(5) The Minister must cause a copy of each report to be tabled in each House of the Parliament within 15 sitting days of that House after the day on which the Minister receives the report.

Definitions

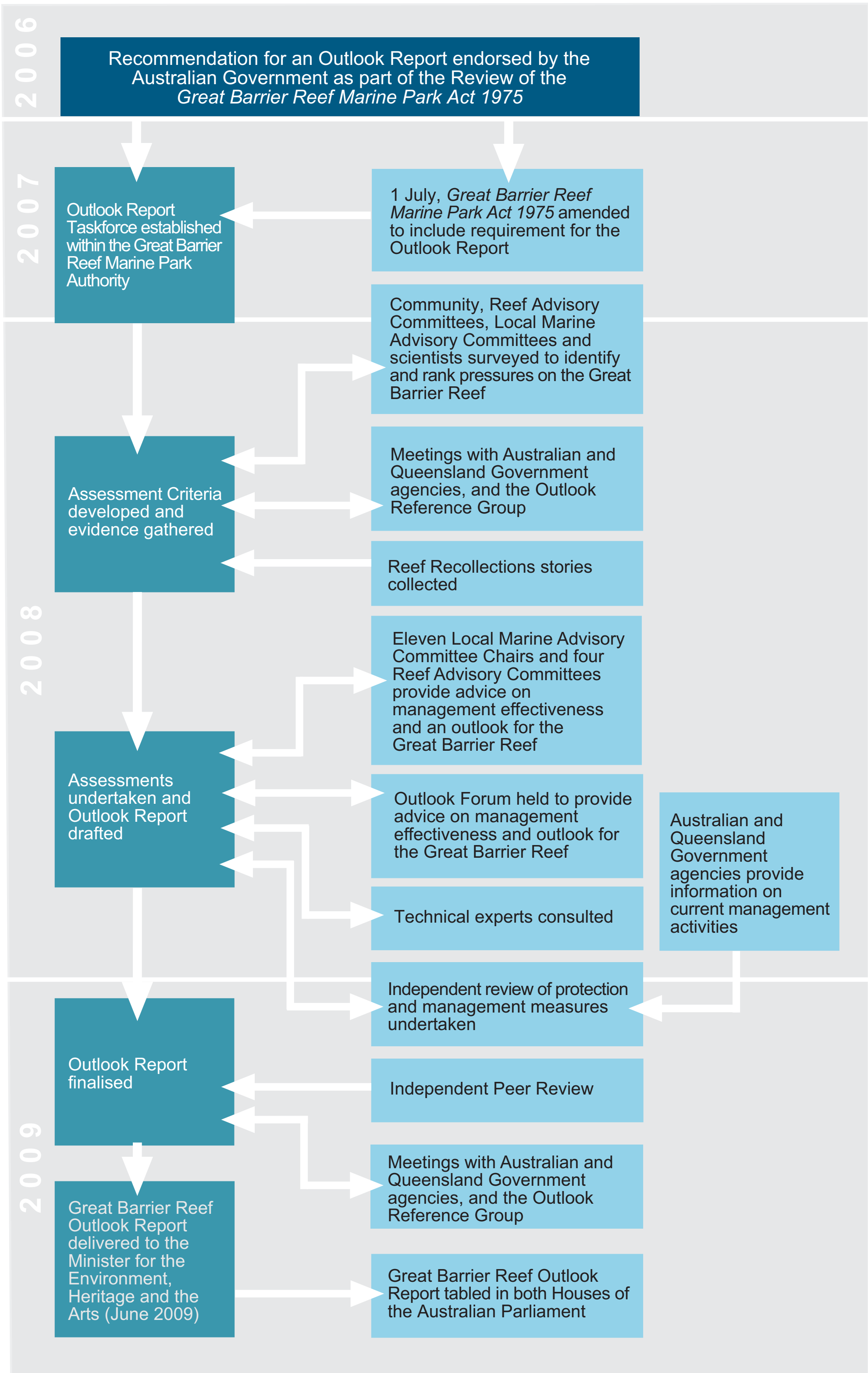
(6) In this section:

biodiversity has the same meaning as in the *Environment Protection and Biodiversity Conservation Act 1999.*

ecosystem has the same meaning as in the *Environment Protection and Biodiversity Conservation Act 1999.*

An extract from the Great Barrier Reef Marine Park Act 1975

APPENDIX 2 Developing the Great Barrier Reef Outlook Report



Threats to the Great Barrier Reef ecosystem

APPENDIX 3

Ideas on current and likely threats to the Great Barrier Reef ecosystem were gathered from a number of sources, including the Great Barrier Reef Marine Park Authority's eleven regionally based Local Marine Advisory Committees and four issues based Reef Advisory Committees. The following final set of 41 threats were considered in the risk assessment (Chapter 8).

- Anchoring on coral by small vessels
- Artificial barriers to riverine and estuarine flow (e.g. dams, weirs, breakwalls and gates)
- Boat strike leading to death in species of conservation concern
- Clearing or modifying wetlands, mangroves and other coastal habitats
- Climate change induced altered ocean currents
- Climate change induced altered cyclone activity
- Death of discarded species during fishing or collecting
- Dredging and dumping of spoil
- Extraction of detritivores by fishing (e.g. prawns and sea cucumbers)
- Extraction of filter feeders by fishing (e.g. scallops)
- Extraction of herbivores by fishing
- Extraction of lower order predators by fishing (e.g. coral trout)
- Extraction of top order predators by fishing (e.g. sharks)
- Fishing in unprotected fish spawning aggregations
- Grounding of large vessels
- Grounding of small vessels
- Illegal fishing or collecting (foreign or domestic)
- Incidental catch during fishing of species of conservation concern
- Increasing sea temperature
- Ingestion of or entanglement in marine debris causing death in species of conservation concern
- Introduction of exotic species and diseases from aquaculture operations
- Introduction of exotic species and diseases through use of imported bait
- Introduction of exotic species and diseases through vessel ballast water discharge
- Introduction of exotic species and diseases through vessel hull fouling
- Large chemical spill
- Large oil spill
- Nutrients from catchment runoff
- Ocean acidification
- Outbreak of coral disease
- Outbreak of crown-of-thorns starfish
- Outbreak of *Drupella* species
- Pesticides (including herbicides) from catchment runoff
- Physical impacts of fishing
- Physical impacts of snorkelling and diving activity
- Poaching and illegal harvesting of species of conservation concern
- Sea level rise
- Sediments from catchment runoff
- Small chemical spill
- Small oil spill
- Traditional hunting of species of conservation concern
- Waste discharge from a vessel (including litter and sewage)

APPENDIX 4 Criteria for ranking likelihood and consequence to the Great Barrier Reef ecosystem

A standard set of criteria allows the comparison of different types of threats within the one risk assessment, based on the likelihood and consequence of each threat.

Likelihood

Category	Expected frequency of a given threat
Almost certain	Expected to occur more or less continuously throughout a year
Likely	Not expected to be continuous but expected to occur one or more times in a year
Possible	Not expected to occur annually but expected to occur within a 10 year period
Unlikely	Not expected to occur in a 10 year period but expected to occur in a 100 year period
Rare	Not expected to occur within the next 100 years

Consequence

	Extent of the impact based on current management	
Category	**Broad scale**	**Local scale**
Catastrophic	Impact is clearly affecting, or would clearly affect, the nature of the ecosystem over a wide area. Recovery periods greater than 20 years likely.	
Major	Impact is, or would be, significant at a wider level. Recovery periods of 10-20 years likely.	Impact is, or would be, extremely serious and possibly irreversible to a sensitive population or community. Condition of an affected part of the ecosystem possibly irretrievably compromised.
Moderate	Impact is, or would be, present at a wider level. Recovery periods of 5-10 years likely.	Impact is, or would be, extremely serious and possibly irreversible over a small area. Recovery periods of 10-20 years likely.
Minor	Impact is, or would be, not discernible at a wider level. Impact would not impair the overall condition of the ecosystem, sensitive population or community over a wider level.	Impact is, or would be, significant to a sensitive population or community at a local level. Recovery periods of 5-10 years likely.
Insignificant	No impact or if impact is, or would be, present then only to the extent that it has no discernible effect on the overall condition of the ecosystem.	No impact or if impact is, or would be, present then only to the extent that it has no discernible effect on the overall condition of the ecosystem.

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The Great Barrier Reef Outlook Report 2009
is available at www.gbrmpa.gov.au