Australian Government
Great Barrier Reef
Marine Park Authority

GREAT BARRIER REEF

Outlook Report

2014

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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.

None of the report is intended to have the effect of extinguishing native title.

Letter of transmittal

Hon. Greg Hunt MP
Minister for the Environment
Parliament House
CANBERRA

Australian Government
Great Barrier Reef
Marine Park Authority

Dear Minister

I am pleased to provide the Great Barrier Reef Outlook Report 2014 to you as Minister for the Environment and through you to the Australian Parliament and the people of Australia.

The Great Barrier Reef Outlook Report 2014 has been prepared by the Great Barrier Reef Marine Park Authority based on the best available information. It fulfils the requirements of Section 54 of the Great Barrier Reef Marine Park Act 1975. The report includes nine assessments covering biodiversity, ecosystem health, heritage values, commercial and non-commercial use, factors influencing the Reef's values, existing protection and management, resilience, risks and the long-term outlook for both the ecosystem and heritage values. The contents of the report were independently peer reviewed.

The specific inclusion of 'heritage' is new and responds to both revised requirements of the Act and a World Heritage Committee request (36COM 7B.8) to include an explicit assessment of the Great Barrier Reef World Heritage Area's outstanding universal value in subsequent Outlook Reports.

The legislation requires that an Outlook Report be prepared every five years. As in the first Outlook Report in 2009, this second report identifies that the Great Barrier Reef Region faces significant pressures ranging in scale from local to global. Since 2009, management initiatives and local actions have demonstrated positive outcomes and the Great Barrier Reef is retaining its outstanding universal value as a world heritage area. Nevertheless, extreme weather events, combined with the lag times required for the recovery of key habitats, species and ecosystem processes, have caused the continued deterioration of the overall health of the Great Barrier Reef. The accumulation of impacts, through time and over an increasing area, is reducing its ability to recover from disturbances, with implications for Reef-dependent communities and industries.

Even with the recent management initiatives to reduce threats and improve resilience, the overall outlook for the Great Barrier Reef is poor and getting worse. These findings will be best addressed through coordinated action across governments, industries and the community.

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

Yours sincerely

RReichelt

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

Acknowledgements

The *Great Barrier Reef Outlook Report 2014* 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.

Many Great Barrier Reef scientists willingly contributed their knowledge and information, both formally through a scientific consensus workshop and informally by checking information used in the report to ensure the correct interpretation of results. The scientific consensus workshop was independently facilitated by Greenward Consulting (Trevor Ward).

Members of the Great Barrier Reef Marine Park Authority's twelve Local Marine Advisory Committees (Cooktown, Douglas, Cairns, Cassowary Coast, Hinchinbrook, Townsville, Burdekin/Bowen, Whitsunday, Mackay, Capricorn Coast, Gladstone Region, Burnett) and members of Reef Guardian Councils and Reef Guardian Schools provided advice on relevant aspects during the Report's development.

The independent assessment of the existing measures to protect and manage the Great Barrier Reef was led by Uniquest Pty Ltd (Marc Hockings and Andrea Leverington) with assistance with the defence, ports and shipping assessments by Ground Zero Environmental Pty Ltd (Colin Trinder, John Polglaze). Their report was independently peer reviewed by Brian Gilligan and Bob Spiers, two experts in assessing the effectiveness of protected area management.

Finally, the contents of the Outlook Report were formally peer reviewed by Neil Byron (University of Canberra, Australia), Peter Fairweather (Flinders University, Australia), Terry Hughes (ARC Centre of Excellence for Coral Reef Studies, Australia) and Peter Valentine (James Cook University, Australia).

The Great Barrier Reef Marine Park Authority acknowledges the continuing sea country management and custodianship of the Great Barrier Reef by Aboriginal and Torres Strait Islander Traditional Owners whose rich cultures, heritage values, enduring connections and shared efforts protect the Reef for future generations.

Executive summary

The Great Barrier Reef is an icon under pressure. Everyone's actions, whether big or small, to reduce threats and help restore its condition will improve its outlook. Combined, they will make the Reef more able to recover from the legacy of past actions and better able to withstand those predicted to threaten its future.

In 2009, the Great Barrier Reef was considered to be at a crossroad, with decisions made in subsequent years likely to determine its long-term future. Since then, continuing investment in management of the Reef has had some positive results. For example, pollutant loads entering the Reef have measurably reduced as a result of comprehensive planning and local action, and Traditional Use of Marine Resource Agreements are improving Traditional Owner control of dugong and turtle hunting for traditional purposes.

Notwithstanding positive actions since 2009, the greatest risks to the Great Barrier Reef have not changed. Climate change, poor water quality from land-based run-off, impacts from coastal development, and some remaining impacts of fishing remain the major threats to the future vitality of the Great Barrier Reef.

In recent years, a series of major storms and floods have affected an ecosystem already under pressure. The accumulation of all impacts on the Reef has the potential to further weaken its resilience. This is likely to affect its ability to recover from serious disturbances, such as major coral bleaching events, which are predicted to become more frequent in the future.

The system as a whole retains the qualities contributing to its outstanding universal value as recognised in its listing as a world heritage property. The assessments of biodiversity and ecosystem health show that the northern third of the Great Barrier Reef Region has good water quality and its ecosystem is in good condition. In contrast, key habitats, species and ecosystem processes in central and southern inshore areas have continued to deteriorate from the cumulative effects of impacts. For example, the population of the iconic and culturally important dugong, which was already at very low levels compared with a century ago, has declined further in this part of the Region.

There are good examples of species continuing to show recovery after past significant declines. Populations of humpback whales, estuarine crocodiles, loggerhead turtles and the southern stock of green turtles are all increasing.

An assessment of heritage values was introduced into this report for the first time. It shows that many are inextricably linked to the health of the ecosystem and none more so than Indigenous heritage values. Traditional Owners with connections to the Region maintain their cultural practices and customs; however, these values have deteriorated as changes in coastal environments have reverberated through their culture, both now and in the past.

Some of the Region's historic heritage values are well recognised and managed, especially known shipwrecks and Commonwealth heritage-listed lightstations. Many other places of historic significance are poorly recorded and their condition is not well understood.

The Great Barrier Reef remains a significant economic resource for regional communities and Australia. Major changes to the condition of the ecosystem have social and economic implications for regional communities because some uses, such as commercial marine tourism and fishing, depend on an intact, healthy and resilient ecosystem.

The Great Barrier Reef continues to be valued around the globe, well beyond its local communities. People's experiences while visiting the Reef, combined with strong programs of information, education and interpretation, serve to maintain its social significance.

Climate change remains the most serious threat to the Great Barrier Reef. It is already affecting the Reef and is likely to have far-reaching consequences in the decades to come. Sea temperatures are on the rise and this trend is expected to continue, leading to an increased risk of mass coral bleaching; gradual ocean acidification will increasingly restrict coral growth and survival; and there are likely to be more intense weather events. The extent and persistence of these impacts depends to a large degree on how effectively the issue of rising levels of greenhouse gases is addressed worldwide. The impacts of increasing ocean temperatures and ocean acidification will be amplified by the accumulation of other impacts such as those caused by excess nutrient run-off.

Large areas of the Region continue to be exposed to elevated concentrations of suspended sediments, excess nutrients and pesticides, which are significantly affecting inshore areas along the developed coast. While improving land management practices are reducing amounts entering the Region, there will be significant time lags before improvements are evident in the Region's water quality. Until then, chronic impacts, for example on the recovery of seagrass meadows and coral reefs, and outbreaks of the coral-eating crown-of-thorns starfish are likely to continue.

Intact coastal habitats (for example freshwater wetlands, floodplains and saltmarshes) are vital to a healthy Great Barrier Reef. They are important in the life cycle of some marine species and also play a role in slowing overland water flow and trapping sediments and nutrients. While not on the same scale as historic broadscale clearing, without active planning and management, incremental modification of these habitats is likely to continue based on projected economic and population growth.

Fishing, including recreational, charter and commercial fishing, occurs in many parts of the Region. There have been management reforms in recent decades, such as the use of bycatch reduction devices including those specifically for marine turtles, total allowable commercial catch limits (quotas) for some species, capping commercial fishing licences and fishery symbols, fish size and possession limits, restrictions on fishing apparatus, closed areas and seasonal closures. Notwithstanding these changes, across all fisheries risks to the ecosystem remain, especially from overfishing of some predators, incidental catch of species of conservation concern, effects on other discarded species and fishing of unprotected spawning aggregations. Illegal fishing continues to be a very high risk to the Reef. While understanding of commercial fishing has improved, recreational fishing and the cumulative impacts of fishing remain poorly understood.

Port activities in and adjacent to the Region are increasing and there are proposals for further expansions, including new capital works and continuing or increasing dredging in the coming decade. The direct and flow-on effects of port activities generally occur in areas of the Region that are already under pressure from an accumulation of impacts. Understanding of the ecosystem effects of port activities, in particular the fate of dredge material disposed at sea, is still incomplete but improving. While the effects of port activities are significant, they are relatively more localised than the broadscale impacts from land-based run-off.

Several strategic approaches are underway to address the risks to the Reef's future and improve its resilience. For example, in addition to current major programs such as the *Reef Water Quality Protection Plan 2013*, the 2014 *Queensland Ports Strategy* and the draft *North–East Shipping Management Plan*, a strategic assessment for the Great Barrier Reef Region and adjacent coastal zone has been drafted by the Australian and Queensland governments. A Reef 2050 Long-term Sustainability Plan for the Great Barrier Reef is in preparation during 2014.

The independent assessment of management effectiveness undertaken for this report recognised the difficulties in achieving positive outcomes, given the complexity of the high risk issues, the geographic extent and time scales of the threats and the diminishing resource base to implement actions. This is reflected in the continuing poor outcomes grade for some management topics. The assessment concludes that, while many of the management measures implemented in the Great Barrier Reef Region and beyond are making a positive difference — for example the *Great Barrier Reef Marine Park Zoning Plan 2003* and the *Reef Water Quality Protection Plan 2013* — the ability to address cumulative impacts remains weak.

The independent assessment noted that management measures have improved in a number of areas since the Outlook Report 2009, in part as a result of that report. For example, planning effectiveness has improved for the management of land-based run-off and traditional use, and understanding of the scope of the Region's heritage values has been considerably strengthened. At the same time, more users of the Region and residents and industries in the catchment are adopting best practices and contributing to monitoring to reduce impacts on the Reef and better protect it.

This 2014 Outlook Report, which is based on the best available information, has shown that there have been significant improvements in understanding of the Region's values and impacts since the 2009 report (for example Reef water quality), however important information gaps still exist. In particular, knowledge and understanding of the cumulative impacts of the multitude of uses and activities remains to be developed.

Even with the recent management initiatives to reduce threats and improve resilience, the overall outlook for the Great Barrier Reef is poor, has worsened since 2009 and is expected to further deteriorate in the future. Greater reductions of all threats at all levels, Reef-wide, regional and local, are required to prevent the projected declines in the Great Barrier Reef and to improve its capacity to recover.

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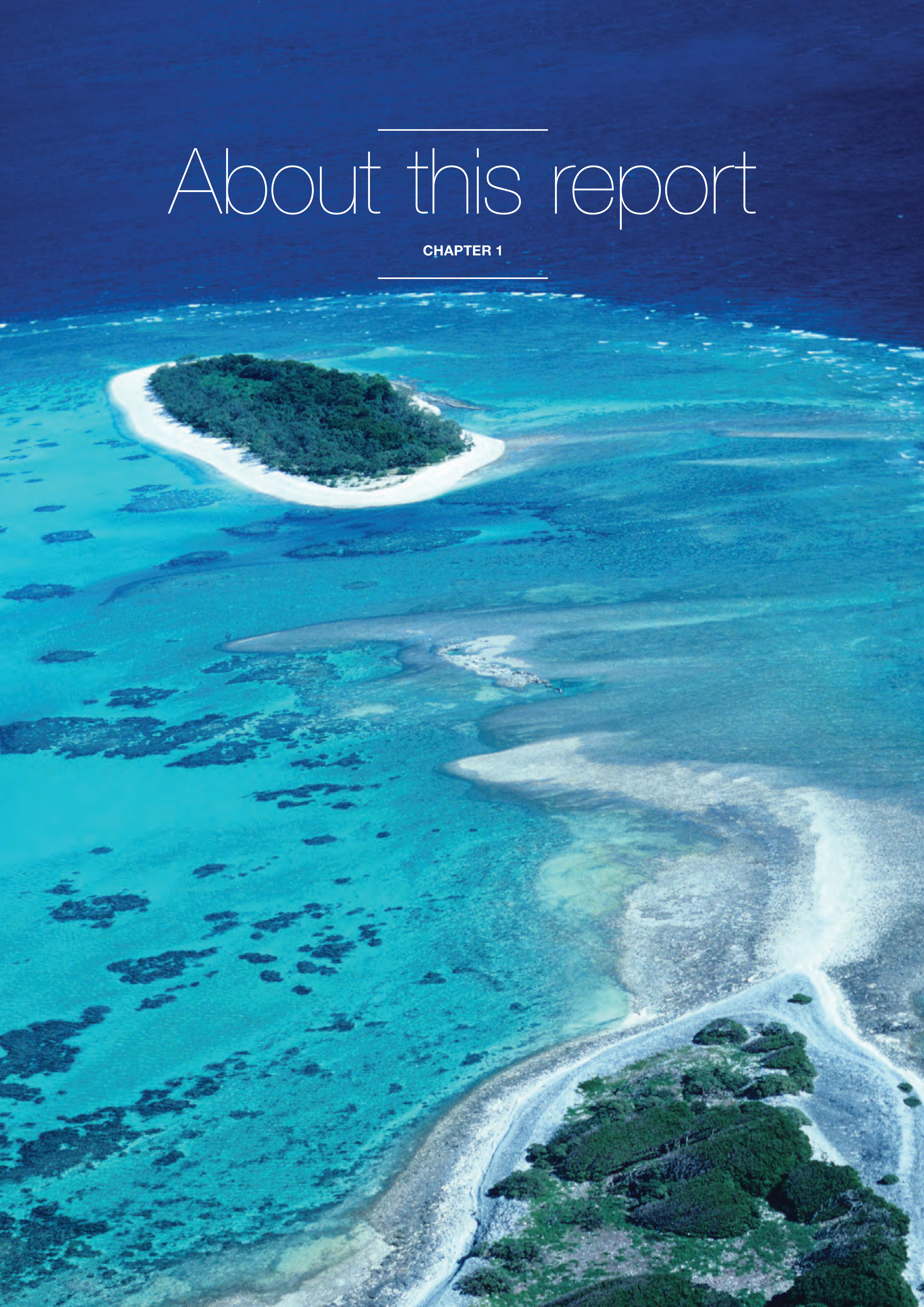
About this report

CHAPTER 1



About this report

1.1 Background

Every five years, the Great Barrier Reef Marine Park Authority prepares an Outlook Report for the Great Barrier Reef (the Reef). The *Great Barrier Reef Marine Park Act 1975* (the Act) and the *Great Barrier Reef Marine Park Regulations 1983* (the Regulations) stipulate what the report must contain and that it must be given to the Australian Government Minister for the Environment for tabling in both houses of the Australian Parliament (Appendix 1).

Outlook Reports are a regular and reliable means of assessing overall performance of all measures to protect and manage the Great Barrier Reef in an accountable and transparent manner. They are a key input for any changes to management arrangements and the consideration of broader issues by government.

The Great Barrier Reef Marine Park Act and Regulations set out what the report must contain.

The first Great Barrier Reef Outlook Report[1] was released in September 2009. As required by the Act, it provided a summary of the long-term outlook for the Reef based on assessments of condition, use, influencing factors, management effectiveness, resilience and risks.

This second report builds upon the first. It provides a snapshot of current condition and examines progress in protecting the Reef since 2009. Importantly, it better encompasses the full range of values. It reflects the 2013 amendment of the Regulations which requires explicit assessment of heritage values in future Outlook Reports (Appendix 1).

1.2 Scope

The area examined in this report is the Great Barrier Reef Region (the Region) as defined in the Act. The Region covers 346,000 square kilometres 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 250 kilometres (Figure 1.1). It includes about 70 Commonwealth-owned islands. However, the majority of islands are owned by the Queensland Government or privately and are not included in the Region.

There are geographically small but important differences between the boundaries of the Region, the Great Barrier Reef World Heritage Area and the Great Barrier Reef Marine Park (Table 1.1). The Region's boundaries match those of the Great Barrier Reef Marine Park, except the Region includes the areas around major ports that are not part of the Marine Park. The Great Barrier Reef World Heritage Area also has similar boundaries to the Region, except that it includes all islands and all Queensland internal waters that are within its outer boundary.

The Outlook Report focuses on the Great Barrier Reef Region and the factors that influence it.

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 the ecosystem components are referred to as the Great Barrier Reef ecosystem or simply the Great Barrier Reef. The report also aims to assess all aspects of the Region's heritage values, from its world heritage values and outstanding universal value to its cultural values and historic places.

Where it is relevant to the Great Barrier Reef ecosystem and its heritage values, the report looks beyond the Region's boundaries and includes information about adjacent islands, neighbouring marine areas and catchments adjacent to the Great Barrier Reef.

As was the case in 2009, the Act does not provide for the Outlook Report to include recommendations about future protection or management initiatives.

Complex and interconnected

Sea country of Traditional Owners

More than 70 Traditional Owner groups

Enduring connections

Continuing sea country management

Part of our identity

A great Australian icon

86% of Australians are proud of its World Heritage status

Supports many uses

Over 1000 current permits for activities like tourism, research and infrastructure

A third of the Marine Park in 'no take' zones

World Heritage

Outstanding universal value because of its habitats, ecological processes, geology and evolution, beauty, and integrity as a system

DIVERSE

Many 1000s of different plants and animals

THE REMARKABLE
Great Barrier Reef

Stretching 2300 km along Australia's coast, the Great Barrier Reef is a national and global treasure. It is managed as a Commonwealth Marine Park by the Great Barrier Reef Marine Park Authority working in partnership with the Queensland Government.

LARGE

Covers 346,000 km^2
~ 70 million football fields

Internationally significant

Valued and visited by people from all over the world

Rich heritage

Managed through partnerships

Field management and compliance

Research and monitoring

Stewardship and best practice

A precious part of our lives

Visited by 44% of Australians and 95% of local community residents

$5.6 billion and 69,000 jobs (2011–12)

1.9 million visits to the Reef on commercial tourism operations (2013)

7900 tonnes of retained commercial fisheries catch (2012)

Resilient but under pressure

Maintaining resistance and ability to recover is critical

World Heritage Area

Marine Park legislation and Great Barrier Reef Marine Park Authority established

Amalgamated Zoning Plan

Marine Park progressively declared

PROTECTED

Almost all of the Great Barrier Reef ecosystem is now included within the Great Barrier Reef Marine Park

Figure 1.1 Great Barrier Reef Region
The Outlook Report is a report about the entire Great Barrier Reef Region.

Table 1.1 Differences between the Great Barrier Reef Region, World Heritage Area and Marine Park

Great Barrier Reef Region	Great Barrier Reef World Heritage Area	Great Barrier Reef Marine Park
Established 1975	Inscribed 1981	Declared in sections between 1979 and 2001; amalgamated into one section in 2003
346,000 km^2	348,000 km^2	344,400 km^2
Includes: • approximately 70 Commonwealth islands • all waters seaward of low water mark (excluding Queensland internal waters) Does NOT include: • internal waters of Queensland • Queensland islands (about 980)	Includes: • all islands within outer boundary (about 1050) • all waters seaward of low water mark (including internal waters of Queensland and port waters) • all 12 trading ports	Includes: • approximately 70 Commonwealth islands • all waters seaward of low water mark (excluding Queensland internal waters) Does NOT include: • internal waters of Queensland • Queensland islands (about 980) • 13 coastal exclusion areas

A place of outstanding universal value

The Great Barrier Reef is a world heritage area, comprising the Great Barrier Reef Region plus Queensland internal waters and islands within its boundaries. The property is recognised as having outstanding universal value: '*natural significance which is so exceptional as to transcend national boundaries and to be of common importance for present and future generations of all humanity*'.[2] Listing of the Great Barrier Reef is based on it having superlative natural phenomena and areas of exceptional natural beauty; it being an outstanding example of major stages in the Earth's evolutionary history; it representing significant ongoing ecological and biological processes and Traditional Owners' interaction with the natural environment; and it containing the most important and significant natural habitats for *in situ* conservation of biological diversity.

Almost all aspects of the Region's environment contribute to its outstanding universal value (Appendix 3) and they are comprehensively considered throughout this report. A compiled assessment of the Region's world heritage values is provided in Chapter 4.

As well as fulfilling the requirements of the Great Barrier Reef Marine Park Regulations, the assessments relating to world heritage values address a recommendation of the 2012 World Heritage Centre/IUCN Monitoring Mission.[3]

The Great Barrier Reef is valued worldwide © Matt Curnock

> *'Include, in the future editions of the Outlook Report for the Great Barrier Reef, and commencing with the version to be published in 2014, a specific assessment on the condition, trends, threats and prospects for the Outstanding Universal Value of the Great Barrier Reef World Heritage Area. The assessment should be benchmarked at the date of inscription of the property in 1981, and its results should be reported to the World Heritage Committee for consideration at its 39th session in 2015.'*

1.3 Structure

This Outlook Report assesses the current condition of the Great Barrier Reef's ecosystem and heritage values and their links with other environmental, social and economic values. It also examines pressures and current responses, and finally considers the likely outlook for the Region's values. It is structured around the nine assessments required by the Act and Regulations, with each assessment forming a chapter of the report (Figure 1.2). The focus of the four chapters on the values of the Great Barrier Reef is their current state and trends. Likely future trends in those values and the factors influencing them are discussed in later chapters, such as those on the factors influencing the values, risks and outlook.

Both ecosystem and heritage values of the Region are assessed.

The findings of the *Great Barrier Reef Outlook Report 2009*[1] are summarised throughout the report. Excerpts of relevant summaries from the previous report are included at the beginning of each chapter and in association with assessment summaries at the end of the chapter.

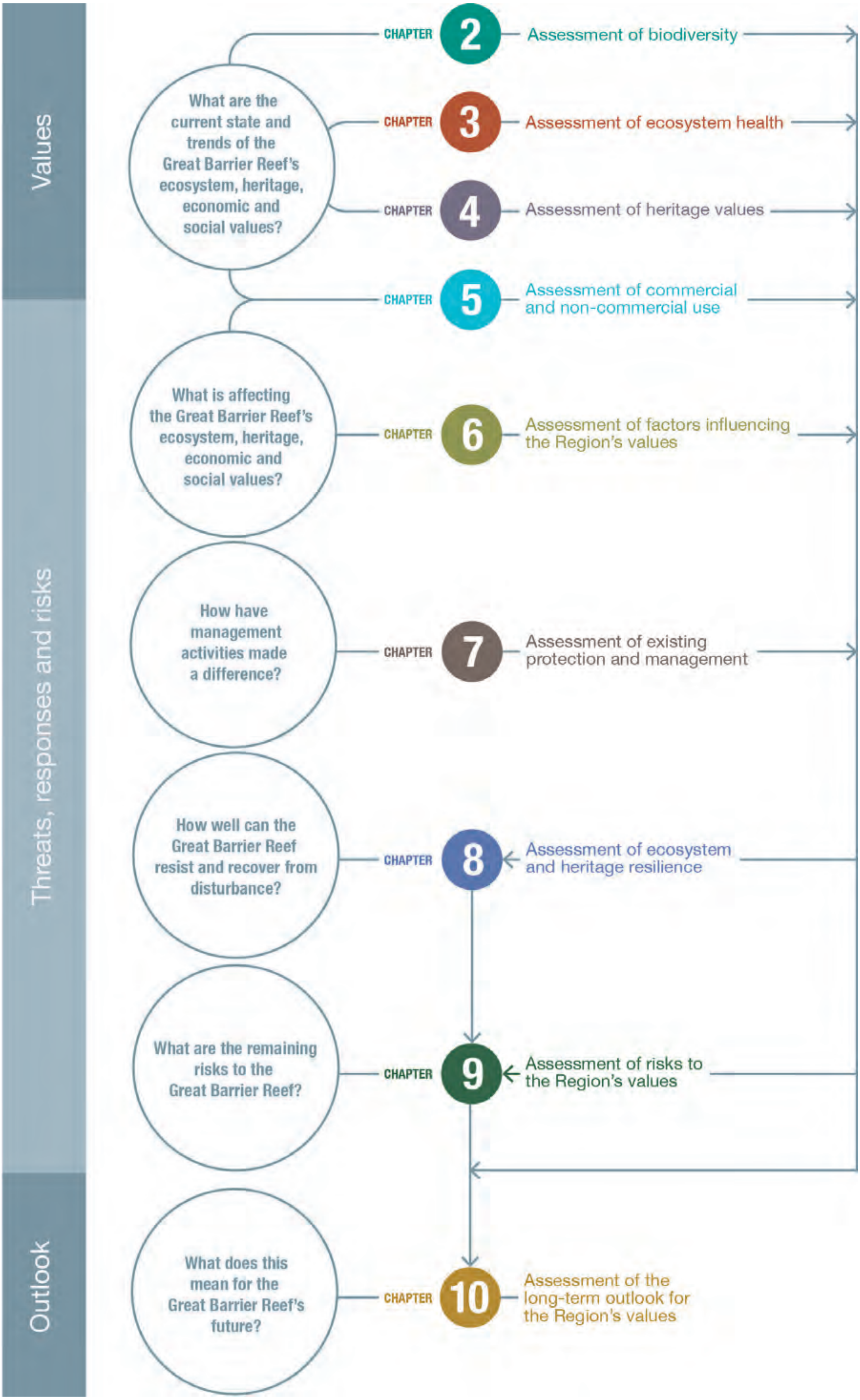


Figure 1.2 Assessments of the report

Each of the assessments required under the Great Barrier Reef Marine Park Act and Regulations forms a chapter of the report. The assessments relating to the Region's ecosystem and its heritage values and those examining the threats, responses and risks inform an assessment of the likely outlook of the Great Barrier Reef.

1.4 Assessment approach

For each of the assessments required under the Act and Regulations, a set of assessment criteria allow an ordered analysis of the available evidence (Figure 1.3). For example, the assessment of biodiversity uses two assessment criteria — habitats to support species and populations of species or groups of species.

The required assessments are structured around assessment criteria.

Within each assessment criterion there are multiple assessment components. In some cases, adjustments have been made to assessment components since 2009. For example, in Chapter 3 the ecological process of recruitment has been added to the assessment, recognising the important role it plays in the maintenance and recovery of ecosystems. In Chapter 5 'Ports and shipping' has been separated into two components, recognising the differences between the two uses, their management and impacts. These changes provide greater clarity and allow better assessment of the condition of values and benefits and impacts of activities.

To maintain the value of the Outlook Report as a time series, changes have been limited to instances where they significantly improve the validity or utility of the assessment. A list of key changes is provided in Appendix 2.

The outcomes for each criterion are provided in an assessment summary at the end of each chapter, along with an overall summary of the assessment findings.

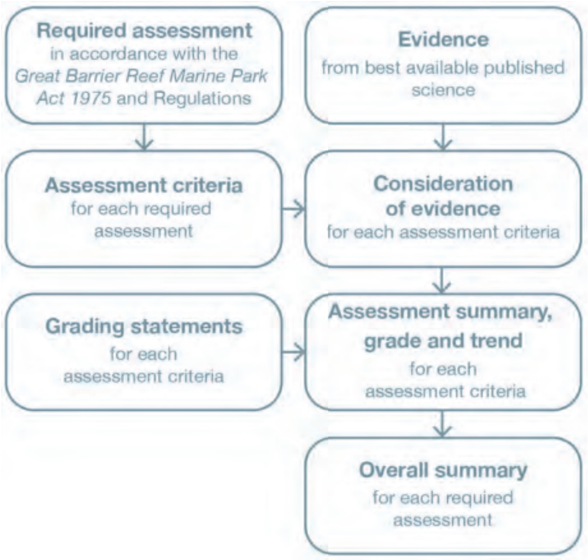


Figure 1.3 Assessment approach
The required assessments are based on the best available evidence. The allocation of grades is standardised through reference to grading statements presented with each assessment summary.

1.4.1 Assessing heritage values

Unlike the first Outlook Report, heritage values, both tangible and intangible, are explicitly considered throughout this report. Assessments of the current state, factors influencing, resilience of, risks to, and long-term outlook of the Region's heritage values are provided. The approaches used are based on those developed for the *Australia State of the Environment 2011*[4] and the 2013 draft *Great Barrier Reef Region Strategic Assessment Report*[5] and will undoubtedly be further refined over time. Likewise, as the amount of heritage information grows, so will the depth of the assessment and the degree of confidence in its findings.

1.4.2 Assessment grades

A series of statements standardise the allocation of grades for all components examined in an assessment, as well as the overall grade for the criterion. These statements are largely the same as for the Outlook Report 2009 — with a few amendments to improve clarity.

The grade allocated is a 'grade of best fit', based on a qualitative assessment of the available evidence for the Region. It is not a comparison of the Region in relation to other tropical ecosystems around the world.

The assessment of heritage values is new; assessment approaches will continue to evolve.

The statements developed for assessing most heritage values are based on those used in the Australian state of the environment report[4] and strategic assessment draft report[5]. Those for the assessment of world and national heritage values are adapted from a grading system developed by the International Union for Conservation of Nature to assess the outstanding universal value of natural world heritage sites.[6] One aspect considered in grading the condition of heritage values is the degree to which those values have been recorded and identified. This recognises the important role an understanding of heritage plays in its protection.

1.4.3 Trend and confidence

The approach to grading is refined by including an indication of trend and confidence, similar to the Australian state of the environment report[2] and the strategic assessment draft report[3]. Trend in each component is assessed in relation to the assessment in the previous Outlook Report, and therefore reflects change over the last five years. In the forward-looking assessments — those relating to the factors influencing the Region's values, risks and outlook (Chapters 6, 9 and 10) — a future trend is also provided.

There are four categories for trend: improved, stable, deteriorated and no consistent trend. The category of 'no consistent trend' is applied to a component when the available information is too variable to establish a trend, for example where there is strong variation across broad areas or across species within a group. The terms 'improved' and 'deteriorated' are replaced with 'increased' and 'decreased' in assessments of benefits, impacts, threats and risks (Chapters 5, 6 and 9).

Trends are not indicated for those components that were not assessed in the Outlook Report 2009, for example the heritage values of the Region (Chapter 4).

Similar to the Australian state of the environment report and the strategic assessment draft report, the level of confidence in each assessment of grade and trend is rated. The categories used are:

- adequate high quality evidence and high level of consensus
- limited evidence or limited consensus
- inferred, very limited evidence.

Trend since 2009 and confidence are presented for most assessments.

For components where the confidence level is 'inferred, very limited evidence', the assessment is based on knowledge from managing agencies, Traditional Owners, topic experts and informed stakeholders.

Confidence levels are not provided for the assessment of existing protection and management (Chapter 7).

1.5 Evidence used

This report contains brief background information on the Region, its ecosystem, heritage values, use and management and the key evidence for the assessments required under the Act and the Regulations.

The information featured in the report is only a small portion of all that is known about the Region. The evidence used is derived from existing research and information sources. It is drawn from the best available published science to the end of 2013 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 Outlook Report is based on the best available evidence.

In some cases, new information that became available after 2013 has been included where it was considered to make a significant difference to a key finding of the report. For example, water quality data have been incorporated from the *Great Barrier Reef Report Card 2012 and 2013*[7], released in June 2014. The sources of the evidence directly used in each chapter are cited at the end of that chapter. The web addresses provided were correct at the time of writing.

Despite the volume of information available, there remain many aspects of the Region, its values, uses and threats (in particular cumulative effects), about which little is known. Significant information gaps are noted in the text.

1.6 Terminology

In the various management, research and monitoring programs relevant to the Reef, there is no common way of dividing up the Region. Throughout this report, three areas are referred to: 'northern', 'central' and 'southern'. These are broadly in keeping with the range of divisions used by managers and scientists. While the boundaries are not precisely defined, the northern area ranges from the tip of Cape York to about the latitude of Cooktown and Port Douglas, which marks the division between the developed and less-developed catchments adjacent to the Region. The central area extends from about Cooktown and Port Douglas to about the Whitsundays and the southern area is the area south of the Whitsundays. The term 'southern two-thirds of the Region' is often employed to describe the combined central and southern areas.

Some research and monitoring results reported specifically relate to a different set of sub-divisions for the Region, for example the natural resource management regions. Where possible, the area relevant to each set of evidence is mapped or described alongside the evidence.

Across the Region, the term 'inshore' is applied to areas within about 20 kilometres of the coast. It corresponds to enclosed coastal and open coastal water bodies described in the *Water Quality Guidelines for the Great Barrier Reef Marine Park*[8] but also includes areas further offshore that are habitats for recognised inshore species such as dugongs. Areas beyond are generally referred to as 'offshore'. For coral reefs, the term 'outer shelf' refers to those along the edge of the continental shelf and 'mid-shelf' refers to those between inshore areas and the outer barrier reefs.

The Region's ecosystem and heritage values are considered, plus their links to economic and social values

1.7 Developing the report

The report has been prepared by the Great Barrier Reef Marine Park Authority. A number of Australian and Queensland government agencies and researchers from a range of institutions directly contributed to its development.

Producing an Outlook Report draws on the expertise and assistance of many people.

The Great Barrier Reef Marine Park Authority's 12 Local Marine Advisory Committees (committees based in regional centres along the coast); industry representatives; local government councils and schools participating in the Reef Guardian program; and other stakeholders supported the report's preparation in various ways. In particular, advice provided during development of the draft strategic assessment report[3] and comments received on the draft report have subsequently informed this report.

The outcomes of a consensus workshop[9] involving about 35 Reef scientists contributed to the assessments of biodiversity and ecosystem health. The outcomes also informed the assessment of risk. The consensus workshop was modelled on those undertaken during development of the 2011 Australian state of the environment report[10].

Four independent experts in protected area management, monitoring and evaluation, public policy and governance independently assessed the effectiveness of existing protection and management arrangements for the Region's ecosystem and its heritage values. The assessment included identifying any gaps or deficiencies and a comparative analysis with the 2009 assessment. The assessors' report[11] forms the basis of the assessment of existing measures to protect and manage the Region (Chapter 7).

Finally, four reviewers appointed by the Minister for the Environment independently reviewed the draft Outlook Report. These reviewers are recognised national and international experts with biophysical, heritage and/or socioeconomic expertise and achievements, including conducting high level policy and scientific reviews. Their comments were considered and incorporated where appropriate in finalising the report.

Comprehensive strategic assessment of the Great Barrier Reef World Heritage Area

Between 2012 and 2014, the Australian and Queensland governments undertook a comprehensive strategic assessment of the Great Barrier Reef World Heritage Area, comprising assessments for the Region[5] and for the adjacent coastal zone[12]. Undertaken under the *Environment Protection and Biodiversity Conservation Act 1999* (Cth), the assessments aimed to improve management of existing and emerging risks to the Great Barrier Reef. They also form part of the Australian Government's response to the World Heritage Committee's concerns regarding development impacts on the World Heritage Area originally raised at its meeting in June 2011.

The strategic assessment process had a different scope and purpose to the five-yearly Great Barrier Reef Outlook Report cycle. Both reports examine the condition, threats, management and likely future of the Great Barrier Reef. While the Outlook Report is a regular assessment of the Region's ecosystem and its heritage values, the strategic assessment was a one-off report that focussed on all matters of national environmental significance relevant to the Region. It also makes recommendations for improvements to management. Matters of national environmental significance are Australia's environmental assets. Those relevant to the Region are world heritage properties, the Great Barrier Reef Marine Park, national heritage places, Commonwealth marine areas, listed migratory and threatened species, and wetlands of international importance.

Because the values and attributes of the matters of national environmental significance are part of the Region's ecosystem and its heritage values, this Outlook Report draws extensively on the information contained in the strategic assessment draft report and has been informed by the public submissions received on that draft.

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Biodiversity

CHAPTER 2

'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*

2014 Summary of assessment

Habitats to support species	Information on the condition and trend of habitats is highly variable with some well known (for example shallower coral reefs) and others poorly known, particularly habitats in remote areas or deep waters (for example Halimeda banks). The habitats of the northern third of the Region are believed to remain in very good condition and are able to support dependent species. Habitats in the southern two-thirds of the Region — especially those inshore — have deteriorated, particularly seagrass meadows and coral reefs.	↓ Good, Deteriorated
Population of species and groups of species	There is only condition and trend information for a limited number of species and species groups; hence the assessment of some components is highly uncertain. Of those for which there is information, there have been significant declines in many, especially in the inshore southern two-thirds of the Region, and some iconic and cultural keystone species. For example, significant declines have been recorded in most hard corals and seagrasses, some fishes and sharks, dugongs, plus some seabird populations. There are four examples of species showing good recovery after past serious declines: humpback whales, estuarine crocodiles, loggerhead turtles and green turtles (southern stock). However, even these species have not recovered to their original numbers. The overall condition of the Region's species appears to have deteriorated significantly and the assessment of 'good' is considered borderline with 'poor'.	↓ Good, Deteriorated

Full assessment summary: see Section 2.5

< Photograph © Chris Jones

Biodiversity

2.1 Background

Outlook Report 2009: 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).

Biodiversity is the variety among all living things. It includes all natural variation, from genetic differences within a species to variations across a habitat or a whole ecosystem.

The Great Barrier Reef is one of the world's most diverse and remarkable ecosystems, with a wide range of habitats and many thousands of different species. The Reef's biodiversity is the basis of its outstanding universal value recognised in its world heritage listing (Appendix 3).

This assessment focuses on the broad habitats that make up the Reef's ecosystem, plus the species and groups of species these habitats support. The species and habitats assessed are consistent with those in the *Great Barrier Reef Outlook Report 2009* with the addition of shorebirds.

2.2 Legacies and shifted baselines

2.2.1 Legacy impacts

Some activities previously undertaken within what is now the Great Barrier Reef Region (the Region) and on its islands have had severe and long-lasting impacts on its biodiversity (Figure 2.1). Most of these activities stopped before the area's protection as a marine park and its recognition as a world heritage area, but their legacy remains. These past activities need to be considered when assessing the current condition and trends of affected habitats and species.

The most significant legacy impacts were from large-scale commercial harvesting, especially of long-lived species such as dugongs, marine turtles, crocodiles and humpback whales.

- Dugongs were harvested for meat, bones, hide and oil.[1] Initially, the number of dugongs taken by commercial harvesting was so high that a scarcity forced a closure of the industry in 1890.[2] Large harvests resumed between the 1930s and 1969.[3]

- It is estimated thousands of mature female green turtles were harvested[2] from 1867 onwards[1,4], primarily to supply meat and soup for export. The harvesting was focused in the Capricorn Bunker group, but occurred as far north as Raine Island.[2]
- Hawksbill turtles were harvested commercially for many decades from 1871, primarily as a source of tortoiseshell. The harvesting concentrated in the northern Great Barrier Reef. By 1900, the hawksbill turtle had been already heavily exploited.[2,5]
- Historically, otter trawling caused hundreds of marine turtles to drown in trawl nets annually and contributed to population declines of some species (especially loggerhead turtles).[6] Mandatory use of turtle excluder devices since the early 2000s has largely mitigated this impact.[6,7,8,9,10]
- It is estimated that, historically, high intensity prawn trawling locally removed about 70 to 90 per cent of seabed animals.[11] Although very few areas of the Region were fished so intensively, scientific evidence shows historical patterns and the amount of trawl fishing resulted in substantial effects and changes to seabed habitats and species at a Reef-wide scale.[11,12,13]
- When hunting of humpback whales ceased in the 1960s[1], the eastern Australian population was less than five per cent of that estimated earlier in the century.

Historical reductions in dugong, green turtle and hawksbill turtle populations have substantially affected those species' ability to recover from more recent impacts.[3,4,5]

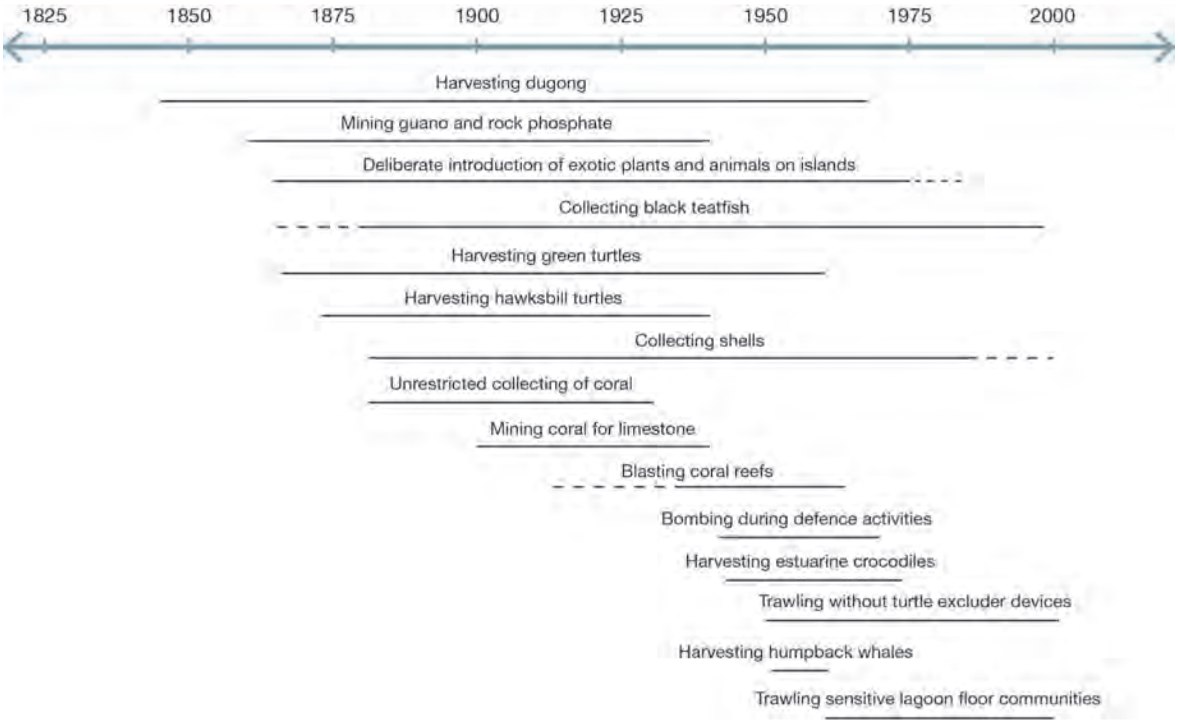

Figure 2.1 Past activities in the Region affecting its biodiversity

Source: Daley 2005[1], Daley *et al.* 2008[2], Limpus 2008[4], Limpus 2009[5], Burridge *et al.* 2003[11], Poiner *et al.* 1998[12], Pitcher *et al.* 2007[13], Daley and Griggs 2008[14], Roelofs 2004[15]

Past commercial harvesting of species such as green turtles seriously depleted their populations

2.2.2 Shifting baselines

When looking at the Great Barrier Reef today, people tend to compare it with their own previous experiences. However, what is considered natural gradually shifts as changes in the environment accumulate — a 'shifting baseline'. Such shifts are particularly an issue in marine environments where the technology to study the ecosystem has been developed only recently. In fact, much marine research has been conducted in ecosystems that are already degraded to some extent, and there is little understanding of how these ecosystems operated in the absence of human activity.[16]

On the Great Barrier Reef, most scientific research and monitoring began in the 1970s and 1980s, but there is increasing evidence of significant changes in the Reef well before then, some stretching back over the past 200 years. The lack of such long-term scientific data across a number of habitats and groups of species presents a significant challenge for assessing the true condition and trend of the ecosystem, including the risk of using a shifted baseline to make the assessment. For example, the first systematic surveys of subtidal reefs in the late 1960s began after an outbreak of crown-of-thorns starfish had affected coral reef habitats along much of the Great Barrier Reef.[16] Understanding the significance of recent declines in coral reefs[17,18] depends critically on the context of those past declines.

Evidence for shifted baselines in the Great Barrier Reef has come from older people who remember how conditions were different[19] or from observations recorded in images such as those of Stone Island near Bowen[20] (Figure 2.2), journals and ships' logs. Traditional Owners and many older people in the broader community[19] consider that fish stocks and other marine resources have declined from the very considerable early bounty that was available on the Reef. Subsequent surveys suggest coral trout stocks on studied reefs were markedly depleted before widespread monitoring began.[21]

Figure 2.2 Inshore coral reefs over time, Stone Island, offshore Bowen
Historical photographs of inshore coral reefs have been especially powerful in illustrating changes over time. The changes in the fringing reefs at Stone Island are typical of many inshore reefs. They largely took place before monitoring programs began — illustrating that modern assessments of the condition of coral reefs are likely to be based on an already shifted baseline. (2012 photograph © The University of Queensland, courtesy of Tara Clark)

2.3 Current condition and trends of habitats to support species

The Great Barrier Reef ecosystem consists of a wide variety of habitats from mangroves and seagrass meadows to coral reefs and open waters (Figure 2.3). Even within each of these habitats there is substantial variation, depending on a complex interplay of ecological factors. Variations of habitats across the continental shelf and beyond — from inshore, shallow water habitats to deep, offshore ocean habitats — are more pronounced than those along the length of the Reef.[22] The overall condition of the Region's biodiversity depends on maintaining the condition of all its habitats and the interconnections between them. Habitats for the conservation of biodiversity are one of the four criteria on which the Reef's world heritage listing is based.[23]

2.3.1 Islands

The Great Barrier Reef ecosystem includes approximately 1050 islands, comprising coral cays, continental islands and mangrove islands. Of these, 70 Commonwealth islands are part of the Region, with the remainder under Queensland Government jurisdiction. The diversity of islands and the habitats they provide are attributes that contribute to the Reef's outstanding universal value.[23]

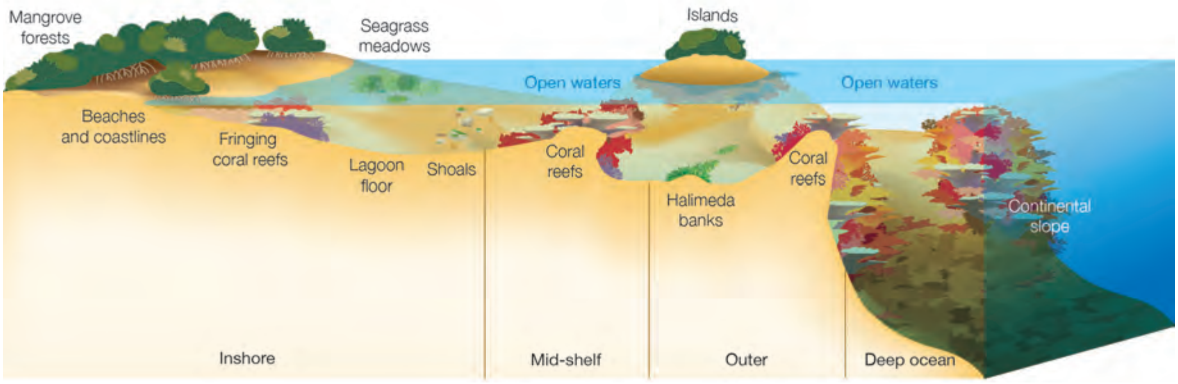

Figure 2.3 Major habitats of the Great Barrier Reef Region
A wide variety of habitats make up the Great Barrier Reef ecosystem. The most pronounced variation is across the continental shelf from the inshore coastal habitats, such as mangroves and beaches, eastwards to the continental slope and deep ocean.

Some islands have been affected by cyclones, pests, and the impacts of use.

Several species of terrestrial plants and animals are endemic to Great Barrier Reef islands (such as *Pisonia* forests[24]).[25] Islands also provide important nesting grounds for a number of marine species such as marine turtles and seabirds.[26] There is limited new information and monitoring of the condition of most islands. Recent severe cyclones[27], invasive pests[28] and weeds[29], marine debris, and changes driven by coastal development (Section 6.4) have affected the condition of some islands. Islands are also considered vulnerable to climate change.[25,30,31]

2.3.2 Mainland beaches and coastlines

Some beaches and coastlines have been modified especially around urban centres and ports.

The beaches and coastlines of the Great Barrier Reef ecosystem stretch approximately 2300 kilometres along the mainland coast of Queensland. Sandy shores typically occur on the exposed coastline and are generally a highly dynamic habitat. They support a wide range of species including providing nesting and staging grounds for shorebirds[32] and marine turtles[33]. Muddy shores are generally adjacent to river mouths and estuaries in sheltered areas. They act as depositional areas for sediments and nutrients discharged from the catchment or transported along the coast. Rocky coasts are intermittently distributed, providing habitat for many sessile species such as oysters. Beaches and coastlines in the northern area remain relatively unaltered, except for marine debris brought in by currents and tides, and extreme weather events such as cyclones. Structures such as marinas, groynes and port infrastructure have heavily modified some coastline habitats at a local scale and affected local coastal processes. Sediment supply to some beaches is disrupted by artificial barriers to flow (for example dams and weirs) and mangrove forests have replaced beaches where fine sediments have increased.[34]

2.3.3 Mangrove forests

Mangrove forests are an intertidal habitat of trees and shrubs covering an estimated 2070 square kilometres in and adjacent to the Region.[34] The habitat occurs in sheltered areas where fine sediments accumulate and where there is inundation by seawater during the tidal cycle.[35] The mangrove forests of the Great Barrier Reef are very diverse[36,37,38], with the highest diversity in the far north.[38] Mangrove forests are an integral part of the Reef ecosystem, providing essential structure and habitat for a range of terrestrial, marine and intertidal species. They play a critical role as: a source of primary production and carbon sequestration;

Mangrove forests remain relatively stable and abundance is being maintained.

Mangrove forests are habitat for terrestrial, marine and intertidal species © Chris Jones nursery and breeding sites[39]; depositional areas for suspended sediments from the water; and physical barriers to storms and weather events.[35,40,41] Mangrove habitats are dynamic, with some localised declines and some expansions.[34] In contrast to international trends, the overall condition of mangrove forests in and adjacent to the Region is relatively stable and abundance is being maintained.[34,35,40,41]

2.3.4 Seagrass meadows

Seagrass meadows are an important component of the Reef ecosystem. They are the main food source for dugongs and green turtles; provide nursery habitat for many commercial fisheries species[42,43]; are a major source of primary production[44,45,46] and sequester significant amounts of carbon[47]. Seagrass meadows also contribute to trapping and stabilising large amounts of sediment[48,49] and nutrient cycling[50].

Seagrass meadows grow in estuaries, shallow coastal waters, and in the lagoon — sometimes in association with coral reefs.[51,52,53] Intertidal and shallow subtidal seagrasses (less than 15 metres deep) are estimated to cover approximately 5700 square kilometres.[54] Deep-water seagrasses (deeper than 15 metres) are estimated to cover 40,000 square kilometres, although at these depths seagrass generally becomes very sparse (less than five per cent cover).[53,55,56,57,58]

Many inshore seagrass meadows have declined since 2009.

The earliest 'baseline' for the condition and distribution of seagrass is from 1984 to 1988.[42,59,60] However this baseline may be shifted as hindcast estimates of dugong populations prior to historical commercial harvesting (Section 2.2.1) suggest far more seagrass would have been needed to support larger dugong populations.[3]

The Outlook Report 2009 noted the overall area of seagrass meadows was considered to have been relatively stable over the preceding 20 year period. Since then, monitoring of about 30 intertidal seagrass meadows along the central and southern coast indicates that their overall abundance has declined (Figure 2.4). Other indicators of the condition of seagrass meadows such as reproductive effort and nutrient status have also deteriorated. Shallow subtidal seagrass meadows are less extensively monitored, but many sites also show declines in abundance. Examples of intertidal and subtidal meadows declining include Mourilyan Harbour where seagrass meadows had been consistently present since 1993 but have now almost all been lost[61], as well as substantial reductions in the meadows adjacent to Cairns[52], Townsville[62,63] and Gladstone[64]. Remaining seagrasses are highly vulnerable to further impacts as they have been reduced to small remnant patches and have few seed banks.[65]

These broadscale losses of seagrass abundance are thought to be mainly due to a combination of acute disturbances (for example significant losses occurred between Cairns and Townsville in 2011 due to physical damage by cyclone Yasi[63]) and ongoing chronic impacts such as poor water quality[65] and extended periods of cloud cover in the wet season (which limits growth through a reduction in light). Intertidal and subtidal seagrass meadows that have been relatively unaffected by disturbances since 2012 are showing early signs of recovery beginning with the return of fast-growing pioneer species.[65,66] A more diverse seagrass habitat generally takes a number of years to re-establish.[51,63,67,68]

The abundance and condition of deep-water seagrass meadows is less studied, and few are routinely monitored. In a number of central and northern parts of the Region these meadows are dominated by pioneer species and can be highly seasonal or annual.[69,70] A number of deep-water seagrass meadows affected by floods and cyclones are showing early signs of recovery.[71]

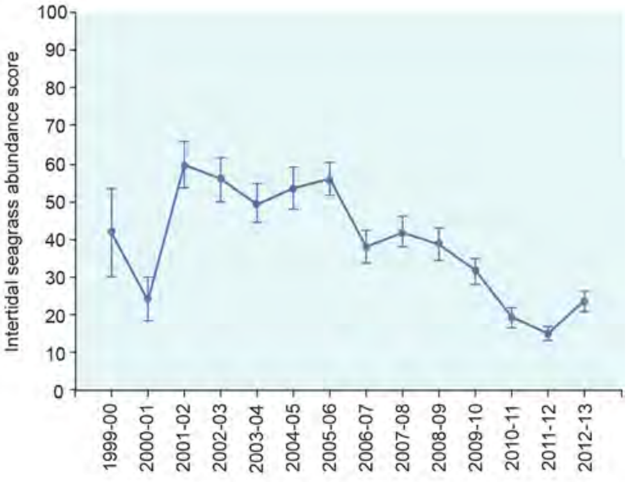

Figure 2.4 Seagrass abundance score for intertidal seagrass meadows, 1999–2013

Substantial declines in the abundance score of intertidal seagrass meadows have been recorded in the Region south of about Cooktown since 2007. Some recovery was observed during 2012-13. Source: McKenzie *et al.* 2014[65]

2.3.5 Coral reefs

Coral reefs are the cornerstone of the Great Barrier Reef ecosystem and its evolutionary history. Their species diversity, habitat value and natural beauty are major contributors to the Reef's outstanding universal value as a world heritage area[23]. The Great Barrier Reef is the world's largest coral reef ecosystem, ranging over 14 degrees in latitude and comprising more than 2900 separate coral reefs[72].

The overall status of coral reef habitats is generally measured by assessing the proportion of a reef covered by living coral — known as coral cover. For the Great Barrier Reef, the most comprehensive, long-term dataset on coral cover is derived from systematic monitoring of a series of reefs since 1985.[18] Results from the monitoring program presented in the Outlook Report 2009 indicated the overall condition of coral reefs in the Region was relatively good, but likely to be declining slightly, especially in inshore areas. It was also reported 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 in the condition of coral reefs across the Great Barrier Reef.

However, recent analysis of the long-term dataset shows hard coral cover has significantly declined over the past 30 years (Figure 2.5).[18] Since 1986, though there have been some periods of recovery, the overall average hard coral cover in the Region is estimated to have declined from 28 to 13.8 per cent and the rate of decline has increased substantially in recent years[18]. The decline has been most severe on reefs south of latitude 20 degrees (near Bowen) particularly since 2006. Since that time, hard coral cover has reduced from about 35 per cent to eight per cent in the southern third of the Region. Hard coral cover in the northern area has not shown similar declines and is in better condition.

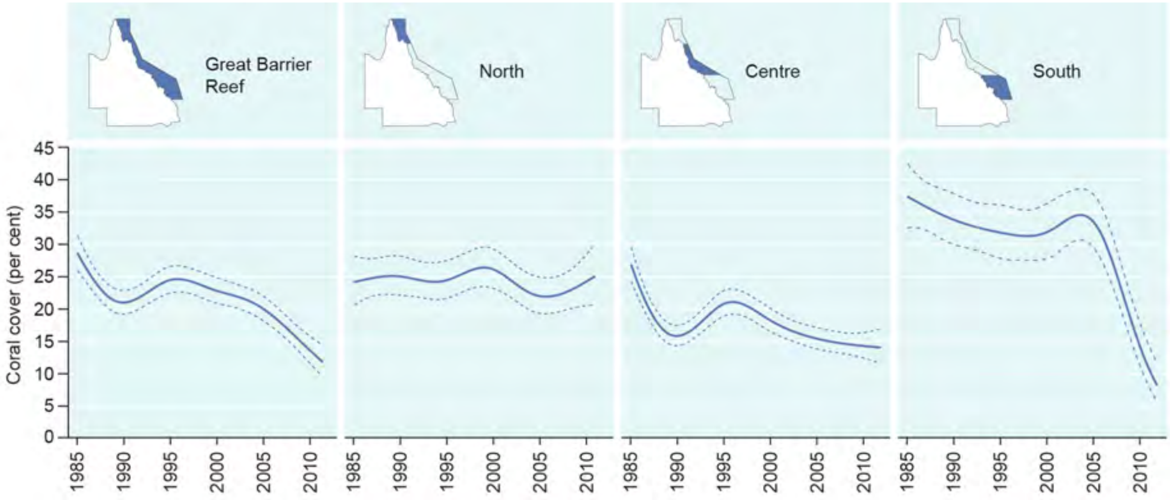

Figure 2.5 Hard coral cover, 1986–2012
The solid line represents modelled coral cover based on the analysis of data collected from 214 reefs across the Region; while the dashed lines either side represent the associated standard errors. Average hard coral cover in the Region has declined significantly since monitoring began in 1986.[18] *Declines have been most severe in the south.* Source: De'ath *et al.* 2012[18]

The recent declines in coral cover are largely the result of a combination of cyclones, crown-of-thorns starfish outbreaks and mass bleaching events, with insufficient time for recruitment and growth between these disturbances (Section 8.3.1).[18,73] Elevated loads of nutrients, sediments and pesticides in land-based run-off are likely to have affected recovery periods in inshore areas.[74,75,76,77] While coral reefs have a natural ability to recover from periodic disturbances, corals exposed to chronic pressures, such as poor water quality, are likely to have less resilience.[78] For example, corals have also been shown to be more susceptible to bleaching and disease in the presence of elevated nutrients.[79,80,81]

There are early signs of regeneration of some reefs affected by cyclone Yasi in 2011. Surveys undertaken in 2013 recorded recovery from fragments and recruitment of new corals.[82]

A series of disturbances has reduced coral cover in the southern two-thirds of the Region.

Data from an inshore marine monitoring program, although over a shorter timeframe, indicates that on average, cover on inshore reefs has declined by 34 per cent since 2005.[77] In addition, there are emerging signs of low coral cover on inshore reefs accompanied by low numbers of juveniles and slow rates of increase in cover during periods free from disturbances.[83]

Assessments of coral reef condition over recent decades are almost certainly from a 'shifted baseline', with the condition of inshore reefs already substantially reduced before monitoring began. Changes in marine water quality associated with land use practices, such as increased nutrient and sediment loads in river run-off, have resulted in changes in coral colonies and communities over time.[76,84,85,86,87] For example, evidence from Pelorus Island (in the Palm Island group, north of Townsville) suggests that, between the 1920s and the 1950s, coral composition changed in favour of those species better adapted to more turbid, muddy waters and in some places little live coral remained.[76] There is evidence, including from historical photographs[20] (Section 2.2.2) and anecdotal reports[19], of other inshore reefs undergoing similar shifts.

Since the Outlook Report 2009, there has been an increase in research on deeper coral reef habitats in the Region–those at depths greater than 30 metres. However, they remain poorly understood compared to their shallow-water counterparts.[88] Mesophotic coral reefs (at depths of between 30 and 150 metres) are characterised by the presence of light-dependent corals in areas where there is limited light for photosynthesis.[89,90] Modelling indicates mesophotic reefs are likely to be widespread along the

Great Barrier Reef shelf edge[91,92] and may add substantially to the known coral reef area in the Region. In fact, about 60 per cent (25,600 square kilometres) of the seabed where coral reefs are likely to grow is deep-water habitat.[93]

There are few indications of recent damage to deeper reefs.

Cold water coral reefs (below 150 metres) typically occur in depths where light does not penetrate and temperatures are between four and 14 degrees Celsius.[94] They can form reefs or knolls and be hotspots of biodiversity on the deep seabed.[95] Although no cold water coral reefs have been identified within the Region, there are locations potentially suitable for them.[96]

There is no long-term data on the condition of deeper reefs; for most of the Region, it is unlikely there has been recent physical damage.[92,95] However, the substantial damage recorded at Myrmidon Reef offshore from Townsville, as a result of the category 5 cyclone Yasi in 2011[97,98], indicates that deeper reefs can also be affected by the physical damage of intense cyclones.

2.3.6 Lagoon floor

The lagoon floor makes up about 210,000 square kilometres, approximately 61 per cent of the Region.[99] It includes the non-reefal seafloor inside the outer barrier reefs, typically at depths of between 20 and 40 metres.[34] The lagoon floor habitat is variable and includes some marine life that rises above the seafloor with sponges, sea-whips, gorgonians (sea fans) and interreefal gardens.[100] The lagoon floor supports many species, such as nematodes and microbial communities, which are important elements of a healthy functioning ecosystem[101]. Larger organisms use the lagoon floor for food and shelter and as a nursery habitat. These include shellfish, crabs, prawns, sea urchins, sea stars, sea cucumbers, sponges, worms, fishes (including sharks and rays) and some marine turtles. The ecological importance of interreefal areas is recognised in the Reef's world heritage listing.

Reduced trawling effort and better management have reduced the area of lagoon floor being affected.

While a large-scale study of the Region's lagoon floor provided a comprehensive and extensive snapshot of the habitat[13], there is no long-term monitoring. In recent years, the area affected by trawling has decreased (Section 5.4.1).[9,102] On a more local scale close to the coast, the lagoon floor is affected by dredging, disposal and resuspension of dredge material, land-based run-off and anchoring.

The lagoon floor and shoals are not well studied

2.3.7 Shoals

Shoals are likely to be affected by physical damage from fishing activities, anchoring, vessel groundings and storms.

Shoals are submerged features on the seafloor away from obvious emergent coral reefs.[103] They include continental rock, and Pleistocene reef edges.[103] They are diverse and variable and attract and support many fishes and other species, such as gorgonians, sponges, algae, macroalgae and seagrasses.[104,105,106] Based on limited studies to date[13,104,107], shoals are likely to be affected by physical damage from fishing activities, anchoring, vessel groundings and storms; however, there is no ongoing monitoring of shoals in the Region.

Figure 2.6 Locations of Halimeda banks
Areas in the Region containing known Halimeda banks are indicated. The banks are dominated by Halimeda algae, and provide habitat for a range of other species. Those in the north are particularly well developed. Source: Australian Institute of Marine Science 1988[114], Drew and Abel 1988[115], Orme and Salama 1988[110], Pitcher *et al.* 2007[13], Hurrey *et al.* 2013[116]

2.3.8 Halimeda banks

Halimeda banks comprise large areas of the northern Great Barrier Reef, inshore of the Ribbon Reefs, and are also found further south (Figure 2.6).[13] They have a thin top layer of living macroalgae — predominantly calcareous green algae (*Halimeda* species) which forms banks when it dies[108], typically up to 20 metres thick[109,110]. They are usually in waters deeper than 40 metres.[111] The active calcification and accretion of Halimeda banks over thousands of years is recognised as one of the Reef's attributes that contributes to its outstanding universal value.

As reported in Outlook Report 2009, there remains limited information on the condition and trend of this habitat. Halimeda banks are isolated from land-based impacts and have a high level of protection from trawling through zoning.[9] The future condition of Halimeda banks is likely to be affected by declining rates of calcification from changes in ocean chemistry[112] and any changes in nutrient upwellings[113] because of changes in ocean circulation.

2.3.9 Continental slope

The continental slope is a complex area composed of relic reefs, landslides, canyons and plateaux that extends down to more than 1000 metres.[117,118] It comprises approximately 15 per cent of the Region or about 51,900 square kilometres.[8] The continental slope supports many species, including some at-risk skates and rays.[9,119] There has been little investigation of this remote habitat or the deep-water seabed habitats beyond and no ongoing monitoring.[8]

Much of the continental slope remains undisturbed.

A deep-water trawl fishery (from 90 to over 200 metres deep) has been operating in continental slope habitat in the south-eastern part of the Region for several decades, with high levels of fishing effort.[9,120] Based on the amount of fishing effort and a lack of knowledge about habitats and associated species, trawling has been graded as presenting a precautionary high ecological risk in the area that includes these fishing grounds.[9]

2.3.10 Open waters

The Region has a total water volume of around 7200 cubic kilometres.[121] This open water habitat is critical to the healthy functioning of the whole Great Barrier Reef ecosystem. It provides connectivity between other habitats, from the coast to beyond the continental slope. Open water is dominated by microorganisms (plankton) and supports a range of other plants and animals such as invertebrates, fishes, reptiles and marine mammals. Inshore areas of open water have been degraded, particularly in the southern two-thirds of the Region. Elevated concentrations of nitrogen and suspended sediment are affecting the overall quality of this habitat[122], especially inshore, for a range of dependent species. Offshore and northern open water areas are considered to be in better condition (Figure 6.12). More information on the condition and trends in water quality of the open water habitat is provided in Chapters 3 and 6.

Inshore open water habitats are degraded in the southern two-thirds of the Region.

Open waters connect the Reef's habitats © Chris Jones

2.4 Current condition and trends of populations of species and groups of species

The Region is home to thousands of species (Table 2.1). It provides particularly important habitat for species of conservation concern such as dugongs, whales, dolphins, seabirds, marine turtles, sharks and rays. Inscription of the Great Barrier Reef on the World Heritage List recognises the global significance of its species diversity, especially its endemic species.[23] It is recognised that there are many new species yet to be discovered and named.[13]

The Great Barrier Reef is home to many species of conservation concern.

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:

- **Threatened species** Twenty-five marine species that occur in the Region are listed as 'vulnerable', 'endangered' or 'critically endangered' under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and are therefore matters of national environmental significance. There are seven marine reptiles, five marine mammals, seven sharks and rays and six seabird species (Table 2.1). The Great Barrier Reef is vital to the recovery and survival of many of these.
- **Migratory species** The Region supports 76 of the migratory species currently listed under the EPBC Act, making them matters of national environmental significance. This comprises six marine turtle species; 11 mammal species including dugongs and two inshore dolphins; five species of shark; 53 species of shorebirds and seabirds; and the estuarine crocodile (Table 2.1). The fact that these species move during their life histories — sometimes very large distances — means they may spend much of their time outside the Region and hence may be exposed to impacts well beyond the boundaries of the Region or Australia.
- **Iconic species** These are well-known plants or animals, such as sea snakes, seahorses, Maori wrasse, whales and dolphins, which often need specific management in the Region.
- **'At risk' species or habitats** These are not necessarily protected by legislation, but are facing serious pressure and require special management. Examples include some coral reefs, giant clams, triton shells, seagrass meadows and some sharks and rays.

Table 2.1 Species diversity of plants and animals
Thousands of species make up the Great Barrier Reef ecosystem. Many have not been identified and described. For some, the number of species recorded is provided; for others the most up-to-date estimate is given.[9,123,124] *The sub-Antarctic fur seal, a threatened species, is rarely seen within the Region. The table includes the number of listed migratory species (M) and listed threatened species (T) under the Environment Protection and Biodiversity Conservation Act 1999.*

Plants and animals of the Great Barrier Reef	Number of species recorded
Mangroves	39
Seagrasses	15
Marine macroalgae	630
Sponges	at least 2500
Soft corals and sea pens	at least 150
Hard corals	411
Echinoderms	630
Crustaceans	about 1300
Molluscs	as many as 3000
Worms	at least 500
Bony fishes	1625
Sharks and rays	136 (M:5, T:7)
Sea snakes	14 breeding species
Marine turtles	6 (M:6, T:6)
Crocodiles	1 (M:1, T:1)
Seabirds	20 nesting species (M:23, T:6)
Shorebirds	41 (M:30)
Whales and dolphins	more than 30 (M:10, T:4)
Dugongs	1 (M:1)

2.4.1 Mangroves

The Region's mangrove forests are very diverse with at least 39 mangrove species and hybrids recorded.[34,36,37,38] The diversity and abundance of mangrove species along the Great Barrier Reef coast are being maintained.[34]

2.4.2 Seagrasses

The Great Barrier Reef is one of the most species-rich areas for seagrass in the world.[125] Fifteen species (which is half of Australia's total number of species) occur within the seagrass meadows of the Region.[57,126,127] There is no record of species loss from the Region[65,128]; however, between 2007 and 2011 there were significant declines in abundance (Section 2.3.4) and shifts in species composition in the inshore southern two-thirds of the Region.[52,63,66] The species composition of seagrass meadows changes as the habitat recovers from disturbance. Early recovery begins with fast-growing pioneer species and the species composition gradually becomes more diverse, dominated by longer lived, slow-growing foundation species (Figure 2.7).

Seagrass abundance has declined and community composition has changed in central and southern inshore areas.

2.4.3 Macroalgae

There are over 600 species of macroalgae recorded on the Great Barrier Reef.[129] Algal communities are highly variable in species composition and abundance.[130] Some are also highly seasonal.[130] Forms of macroalgae include turf algae, fleshy macroalgae and crustose coralline algae. Macroalgae also form dominant cover

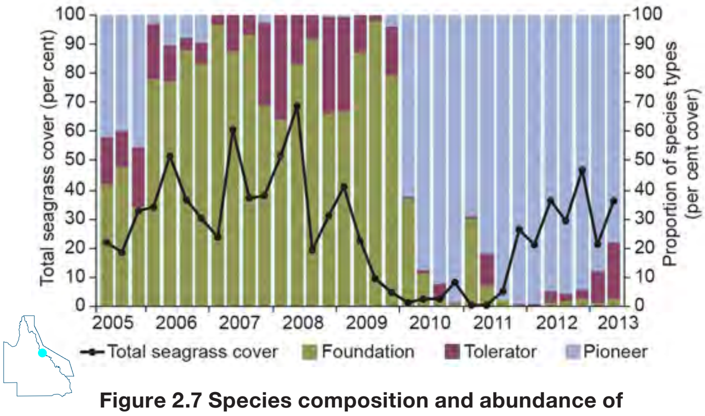

Figure 2.7 Species composition and abundance of seagrass, Cockle Bay, Magnetic Island, 2005–2013

Fast-growing pioneer species are likely to be the first to colonise a disturbed area; however, as meadows grow over time in the absence of disturbances, the longer lived foundation species become more prevalent. Species composition is then likely to remain stable until the next cycle of disturbance and recovery. Source: Adapted from McKenzie *et al*. 2014[65]

in many non-reef areas such as parts of the lagoon floor.[13] Macroalgae forms an extensive and important habitat covering between 25,000 and 30,000 square kilometres of the Region.[116] Algal diversity is greatest off the coast of Gladstone, Rockhampton and Townsville and lowest in areas characterised by high turbidity and muddy sediments.[116] Thirty-six species of macroalgae are classified as 'vulnerable' or 'vulnerable within a narrow range'.[131]

Some fleshy macroalgae are likely to benefit from increased nutrients from land-based run-off but this is likely to be detrimental to natural macroalgal community composition.[132,133] Nutrients can cause a shift in the balance between macroalgae and corals (Section 3.4.9).[134]

In 2011 cyclone Yasi caused a short-term reduction in algal cover on inshore reefs in the central part of the Region with cover re-establishing or exceeding pre-cyclone levels in 2012.[83]

The diversity of macroalgae is being maintained and abundance has increased in some areas.

The abundance of inshore macroalgae is considered to be generally stable, but some locally significant changes have been recorded in the Fitzroy region (Figure 2.8).[83] Between 2005 and 2007 there was an increase in macroalgal cover in the Fitzroy area, partly as a result of the coral bleaching mortality event in 2006[135]; then in 2010 and 2011, declines in cover followed storm events and associated flooding of the Fitzroy River.[83] From 2011, macroalgal cover increased again, probably as the loss of coral cover from the flooding created additional space for growth.[83]

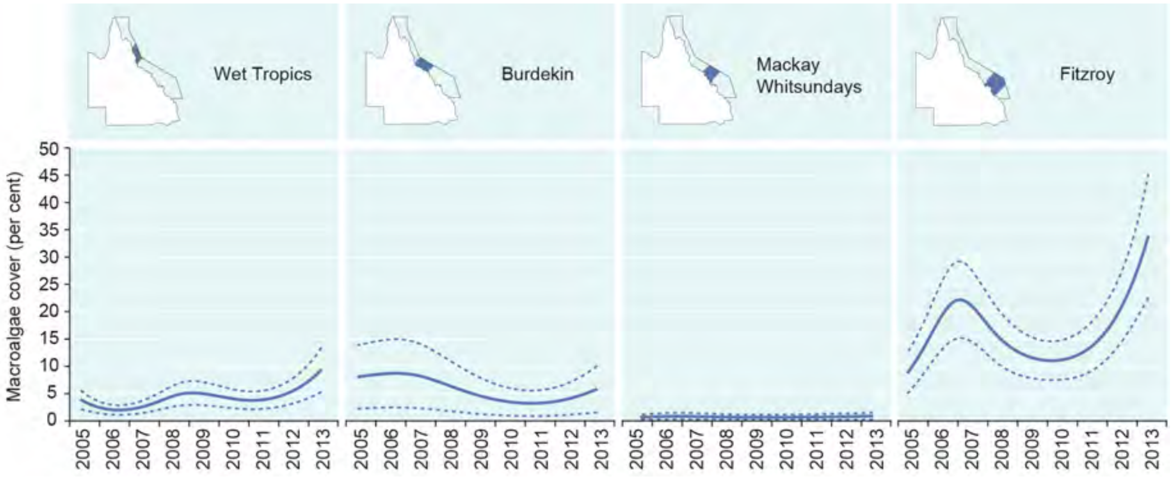

Figure 2.8 Regional trends in inshore macroalgae cover, 2005–2013

The abundance of macroalgae is stable at a Reef-wide scale, but there have been marked regional changes over the last decade. Solid blue curves represent predicted regional trend bounded by blue dashed lines depicting the 95 per cent confidence intervals of that trend. Data presented in graphs relate to macroalgae cover in inshore areas of mapped regions above. Source: Thompson *et al.* 2014[78]

2.4.4 Benthic microalgae

Benthic microalgae are likely to have benefited from elevated nutrients.

Benthic microalgae are microscopic plants which grow on habitats comprising hard bottoms and sandy or muddy sediments. These algae play important roles in primary production and nutrient dynamics in the Region's ecosystem.[136] The biomass of benthic microalgae is typically several orders of magnitude higher than that of plants in the water column (phytoplankton).[136,137] These species are little studied and understanding of their condition, distribution and trend has not improved significantly since the Outlook Report 2009. It is assumed they experience similar disturbances to those identified for the lagoon floor (Section 2.3.6). Some are likely to have benefited from elevated nutrient levels.

2.4.5 Corals

There are more than 400 species of hard coral[138,139] and at least 150 species of soft corals, sea fans and sea pens[140] in the Region. Coral diversity contributes strongly to the outstanding universal value of the Great Barrier Reef World Heritage Area[23]. Recent studies indicate deeper, mesophotic reefs have a higher coral diversity than previously thought.[88,92] In addition to the decline in hard coral cover described in Section 2.3.5, there is also evidence of changes in species composition on reefs. Evidence from Pelorus Island (in the Palm Island group, north of Townsville) indicates that the community composition of inshore coral reefs changed over the last century.[76] Historically, the reefs were dominated by *Acropora* corals, thought to be characteristic of less polluted waters.[76] However, between 1920 and 1955, the coral composition changed and either shifted to corals typical of more turbid, muddy waters or had little live coral.[76] More recently, chronic impacts of poor water quality and outbreaks of disease have resulted in a loss of sensitive species in affected inshore areas and therefore reduced species diversity.[78]

The community composition of inshore coral reefs changed over the last century.

Soft coral cover in inshore areas has been generally stable over the period 2005 to 2010 with some decline in 2011 in the central area caused by physical destruction of colonies by cyclone Yasi.[83] Record flooding of the Fitzroy River in 2011 also killed almost all shallow-water soft corals (at or above two metres deep) on reefs inshore of Great Keppel Island and caused declines in deeper water.[83]

2.4.6 Other invertebrates

There are thousands of species of invertebrates (animals without backbones) in the Region. This biodiversity is nationally and internationally significant (including as part of the Reef's world heritage listing). 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) are found within the Region.[141] Some groups, such as prawns, crabs and sea cucumbers, are important in fisheries. Fishing activities have reduced abundances of a number of invertebrate species, although no invertebrate species are currently assessed as 'overfished' in fisheries stock status reports.[142] The black teatfish fishery was closed in 1999 following concerns for the long-term viability of the harvested stock and has not been reopened (see Section 8.3.3). There are some concerns about the sustainability of the sea cucumber fishery.[143,144]

Invertebrates are likely to be affected by changing environmental conditions and fishing activities.

Little is known about the condition and trends of most species. Some invertebrate species have been protected (for example tridacnid clams, helmet shell, triton shell). It is likely that deteriorating water quality and the changing condition of southern inshore habitats in the southern two-thirds of the Region has affected dependent invertebrates.

Outbreaks of crown-of-thorns starfish continue to occur on the Great Barrier Reef (Section 3.6.2). There is strong evidence to support a connection between human-related impacts (in particular, nutrients from land-based run-off) and outbreaks of crown-of-thorns starfish.[145,146]

These commensal shrimp are one of the Region's thousands of species of invertebrates

2.4.7 Plankton and microbes

Although plankton and microbes play a vital role in the Great Barrier Reef ecosystem as the foundation of the food web and in many ecological processes, there remains little known about their condition and trend.[147,148] Changes in water temperature and quality are likely to be altering plankton communities which, in turn, will be affecting higher trophic levels.[147,148,149] For example, there is growing evidence that increases in nutrients cause shifts in phytoplankton populations, providing favourable conditions for the development of crown-of-thorns starfish larvae.[146]

Changes in water temperature and quality are likely to be altering plankton communities.

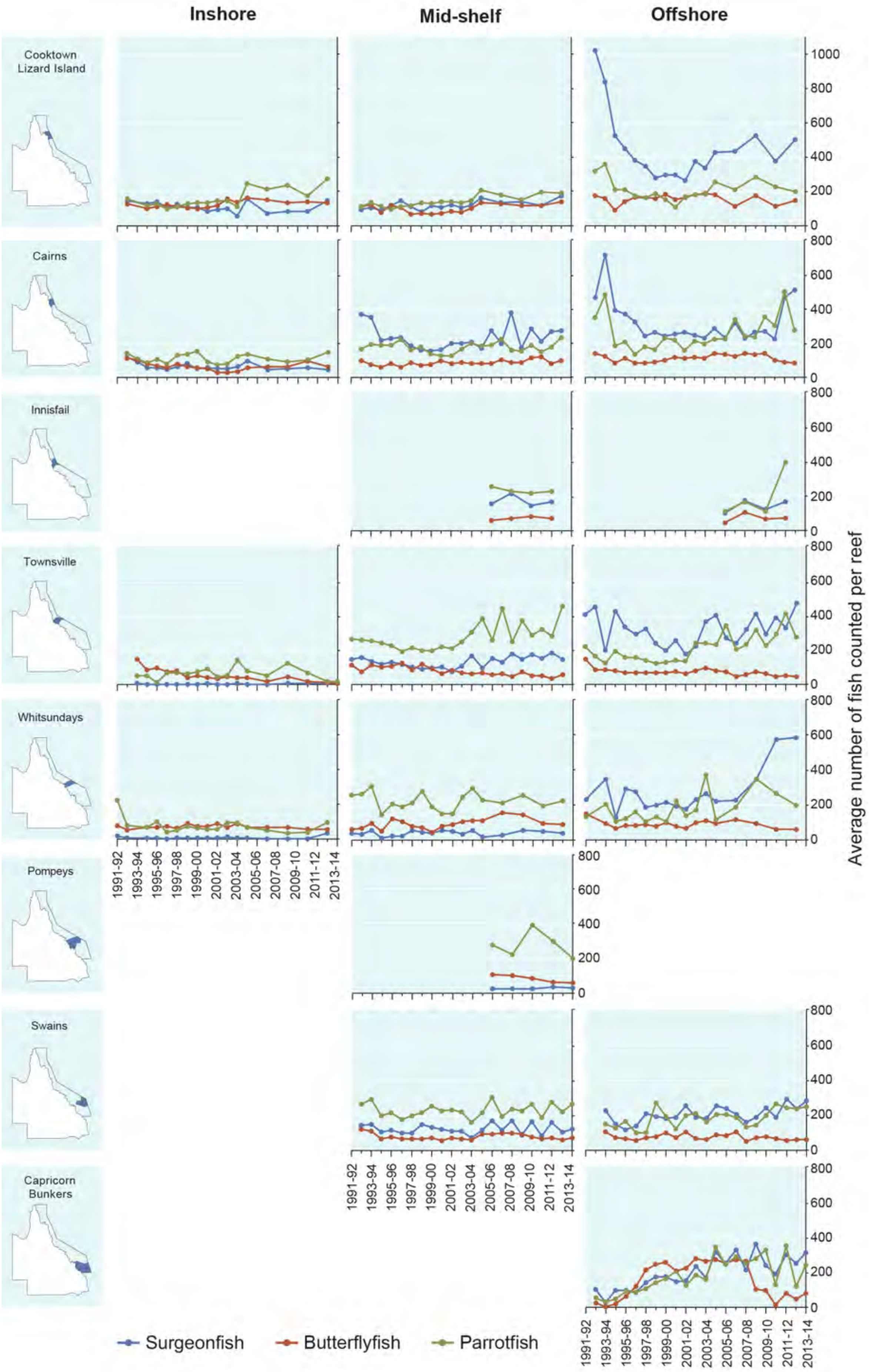

Figure 2.9 Abundance of some coral reef fishes, 1991–2013

Surgeonfish, butterflyfish and parrotfish are examples of how the number of some groups of reef fish changes in different areas of the Region over time. Fish abundance is derived by visual census of a total of fifteen 50 metre by five metre transects at each reef. Where possible three or more reefs were selected at inshore, mid-shelf and offshore positions across the continental shelf. Source: Australian Institute of Marine Science Long-term Monitoring Program 2008[161] and 2014[160]

The condition and trend in phytoplankton abundance are monitored through indicators such as chlorophyll *a*, which is now recorded in the Region via remote sensing as well as *in situ* sampling.[150,151,152,153,154,155,156,157] For the years 2010 to 2012, differences were recorded in the abundance and diversity of the phytoplankton between the northern third of the Region and areas further south, although there is not yet sufficient data to detect trends.[157] While there is still limited information about the condition and trend of zooplankton in the Region, there is now increased data collection[158,159].

2.4.8 Bony fishes

There are about 1600 species of bony fish in the Region. This diversity of species is recognised in the world heritage listing of the Great Barrier Reef.[23]

Decades of research have improved understanding of fish biology and ecology, particularly commercial species, but very little is known about the status of most species.[142] There is long-term monitoring of 214 species of coral reef fish populations[160,161] (Figure 2.9). Fisheries-dependent monitoring provides some information on the trend of a number of species targeted by fishers[162]; however, there is limited fisheries-independent monitoring.

There has been no comprehensive analysis of the long-term trends in the populations of the coral reef fish species that are monitored. Populations of the coral reef fish species are likely to have been affected by the declines in their habitats[163,164] especially in the southern two-thirds of the Region.

Current understanding of fishing activities suggests targeted species are under significantly more pressure in the southern two-thirds of the Region (Section 5.4). These patterns are likely to be similar for non-targeted fish species that interact with the fishery. The condition of northern populations of targeted and non-targeted species is not well known.

The abundance of some fished species has declined.

Of the species targeted in fishing activities, decades of fishing pressure have reduced the size of individual fish, reduced abundances, and contributed to population declines — at least for the more heavily fished species.[165] This is likely to have been exacerbated by extreme weather, reduced habitat availability and declining water quality.[166] Selective fishing can also lead to potentially irreversible evolutionary changes in populations of targeted fish species.[167,168] Zoning arrangements within the Region have been shown to affect the abundance and biomass of targeted species.[169,170,171] The biomass of coral trout, one of the most commonly targeted reef fishes, is greater in no-take zones than in zones open to fishing[165,172] (Figure 2.10).

Life history traits, habitat preferences and cumulative pressures mean that populations of some targeted species may be particularly vulnerable. The vulnerability of two species of threadfin salmon has been assessed as ‘high’.[173] The vulnerability of grey mackerel has been assessed as ‘medium’, with concerns about the future sustainability of stocks in the Region.[174]

Stock assessments undertaken as part of fisheries management provide an indication of the condition of some targeted species. The stock of snapper has been assessed as ‘overfished’ (where harvest may be exceeding sustainable levels and/or yields may be higher in the long term if the effort is reduced) for the past three years.[142] The stock status of Spanish mackerel could be approaching ‘overfished’.[175] In 2012, the stock status of coral trout moved from ‘sustainably fished’ to ‘uncertain’ due to low catches and catch rates.[142] The ecological consequences of reduced fish populations and biomass, for example flow-on effects to other trophic levels, are largely unknown. The biology of some of these fishes (for example being long-lived, late maturing or forming aggregations for spawning) makes them vulnerable to depletion.[176] In addition, fishing activity, including illegal fishing in zones closed to fishing, has contributed to population declines of some targeted fish species.[171]

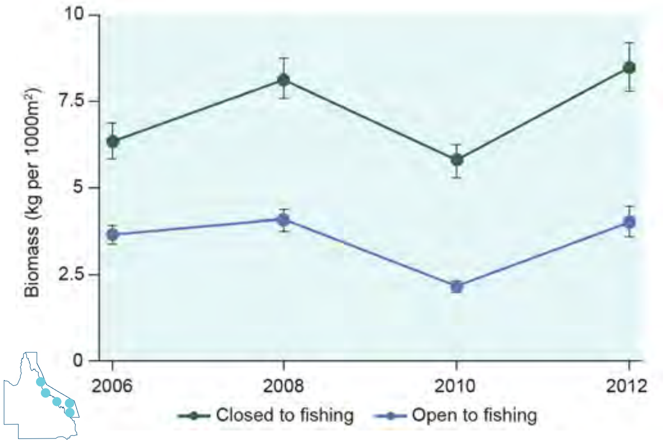

Figure 2.10 Biomass of coral trout in zones open and closed to fishing, 2006–2012

There is more biomass of coral trout on reefs that are closed to fishing. The graph shows the biomass of coral trout (mean plus or minus one standard error) averaged from surveys of 28 pairs of reefs (one open to fishing, one closed to fishing in 2004) in five areas of the Great Barrier Reef. The data was collected using underwater visual census along transects on the reef slope of northeast flanks of each reef. Source: Australian Institute of Marine Science Long-term Monitoring Program[160]

Zoning benefits biodiversity

Zoning, a system of spatial planning and management, is one of the key management tools for the Great Barrier Reef. The amalgamated *Great Barrier Reef Marine Park Zoning Plan*[177] and the complementary *Marine Parks (Great Barrier Reef Coast) Zoning Plan*[178] were implemented in 2004. They provide for a range of ecologically sustainable uses, principally by defining the activities that are allowed, those that are prohibited, and those requiring a permit in each of seven zones. Their design and implementation set a global standard for marine reserve networks[179,180] and they are recognised as having a wide range of benefits for biodiversity, with flow-on benefits for uses of the Region[21].

There is strong evidence that fish populations benefit from the protection provided by the Marine National Park (green) zone which is closed to fishing. There are consistently more and larger coral trout and other target fish in zones protected from fishing.[21,169,172,181] Increased reproduction in the no-take zone as a result of more and bigger fish appears to also benefit fish populations in the entire ecosystem.[182] Importantly, the zones operate as a connected network; most reefs (both open and closed to fishing) are within the range of dispersal from a reef closed to fishing.[21,183,184]

A network of zones is benefiting biodiversity

The zoning arrangements appear to benefit overall ecosystem health and resilience. Areas closed to fishing have served as refuges for fish after acute disturbances such as coral bleaching and flood events.[165] Even highly vulnerable species, such as dugong and marine turtles, may benefit from the zoning arrangements, despite the area of each zone being much smaller than the ranges of these species.[21,185,186]

The effectiveness of zoning depends critically on effective compliance — even a relatively small amount of illegal fishing can have ecologically serious impacts. There is evidence that some areas in zones closed to fishing may be significantly depleted due to illegal fishing[21] implying that the ecological benefits of the zoning could be greater still with better compliance.

Given the major threat posed by climate change, the zoning network provides a critical and cost-effective contribution to enhancing the resilience of the Great Barrier Reef.

2.4.9 Sharks and rays

There are 136 shark and ray species known to inhabit the Region.[9,187] Five are listed migratory species and seven are listed threatened species. Of the listed species:

- There have been significant range contractions and population declines recorded for the largetooth (previously called the freshwater), green and dwarf sawfish.
- The speartooth shark has now become extinct on the east coast of Australia.[188]
- The whale shark, shortfin mako, longfin mako and porbeagle shark are pelagic species for which there is no information on status and trends.
- The white shark and grey nurse shark are temperate species which are rarely sighted in the Region. A 2011 satellite tagging study revealed grey nurse sharks occupying deep-water habitats within the Region.[189]

One species of shark is likely to be near extinction or extinct in the Region.

While understanding of the life history traits of some of the Region's shark and ray species has improved since 2009[190], there is still limited information about the population status of many. There are concerns about the condition and vulnerability of a number of shark and ray species:

- Seventeen currently caught shark species have been assessed as particularly vulnerable to exploitation[191], principally due to slow growth rates, slow maturity and low reproductive rates.
- There is concern for some species or groups of species including the grey and whitetip reef sharks,[192,193] hammerhead sharks[194], as well as some sharks and rays that interact with fisheries.[9,195,196]
- Species which use inshore, coastal and estuarine habitats almost exclusively or at specific times in their life cycles are the most affected by cumulative human-induced impacts.[191,197,198]
- Green sawfish, the Australian blacktip shark, the pigeye shark and the blacktip reef shark are among the most vulnerable species that interact with the East Coast Inshore Fin Fish Fishery.[196]
- Exploitation presents a risk to a number of batoids (including rays, skates, stingrays, guitarfishes and sawfishes).[199] Shark-like batoids are particularly vulnerable to incidental capture in nets set in inshore waters due to their body shape and preference for inshore habitats.[200]

The condition of most shark and ray species is unknown; many are considered at risk.

- While the ecological risk of trawl fisheries to large sharks and rays has been significantly reduced through the introduction of mandatory excluder devices, many smaller species of sharks and rays remain in the bycatch of prawn and scallop trawlers (Section 5.4.3).[9,201]

There is limited information on the distribution and habitat use of either the pelagic or deep-water shark species of the Region.[191] Deep-water species of sharks and rays have lower growth rates, later age at maturity, and live longer than both shelf and pelagic species, meaning their populations will take longer to recover from exploitation or other factors causing declines.[119]

2.4.10 Sea snakes

There are 16 species of sea snakes recorded in the Region with 14 species maintaining permanent breeding populations.[202] In general, sea snake species richness declines from north to south.[203]

While the broad distributions have been documented[203,204], information about the distribution and abundance of individual sea snake species is limited, in part due to logistical difficulties associated with counting sea snakes.[205] Hence, there is little information and no regular monitoring of population trends.

The trawl fishery continues to interact with and cause mortality to sea snakes. Of the large number of sea snakes caught as trawl bycatch each year (estimated to be over 100,000), it is estimated that about 26 per cent die.[204] Reduction in trawl fisheries effort (Section 5.4) and management initiatives promoting the adoption of fisheye bycatch reduction devices are likely to have reduced impacts on some sea snakes. Two species of sea snakes, the ornate reef sea snake and the elegant sea snake, have been identified as being at high risk to the impacts of otter trawling, and two species, the spectacled sea snake and the small-headed sea snake, as at intermediate risk.[9,204]

A large number of sea snakes are caught as bycatch.

Sixteen species of sea snakes are recorded in the Region © Matt Curnock

2.4.11 Marine turtles

Six of the world's seven species of marine turtle occur on the Great Barrier Reef, with globally significant nesting areas for four species: loggerhead, green, hawksbill and flatback turtles.[206] The international importance of the Reef's marine turtle populations, including the significance of Raine Island as a turtle rookery, is recognised in its world heritage listing.

Within the Great Barrier Reef, 38 islands are identified as being important nesting sites for marine turtles.[207] Of these, Raine Island supports the world's largest aggregation of nesting green turtles.[208] Other important islands include Milman Island (hawksbill and green turtles), Moulter Cay (green turtles), Wild Duck Island (flatback turtles), Peak Island (flatback turtles) and the cays of the Capricorn Bunker Group (loggerhead and green turtles).[4,5,6,209] Within the Great Barrier Reef there are two distinct genetic stocks of green turtles, a southern stock and a northern stock[210], which experience different pressures.

The number of nesting green turtles from the southern Great Barrier Reef stock increased at 3.8 per cent per year for the four decades up to 2008.[4] In 2011 some 1020 marine turtles were reported stranded on the Region's coast, 879 in 2012 and 483 in 2013 (Figure 2.11).[211] Most were green turtles[212] and stranded in response to reduced availability of seagrass, their primary food source.[66]

In the northern stock of green turtles, long-term data indicates that the number of nesting turtles at Raine Island has increased significantly since the mid-1970s; although the past two decades have seen a plateau and slight decline to the previously sustained increase in nesting numbers.[215] Based on published data (to 2001)[208], the average size of nesting females is decreasing, and the remigration periods for nesting are increasing which is consistent with a decrease in the proportion of older females returning to breed.[4,208] These signs indicate the northern Great Barrier Reef stock of nesting females may be in the early stages of decline.[4,208] There are also concerns about poor hatching success of eggs on Raine Island.

Nesting populations of most marine turtle populations are stable or increasing. Some are in decline and all are conservation dependent.

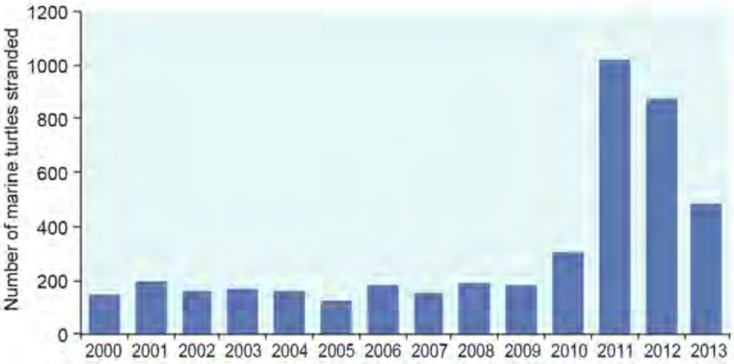

Figure 2.11 Marine turtle strandings, 2000–2013
Marine turtle strandings (dead or alive) in the Region in 2011 were about five times that of previous years. Higher than normal strandings were also recorded in 2012 and 2013. Only cases confirmed in the field by a trained person and later verified by an expert are graphed. Source: Department of Environment and Heritage Protection (Qld)[213] and Department of Agriculture, Forestry and Fisheries (Qld) unpublished data[214]

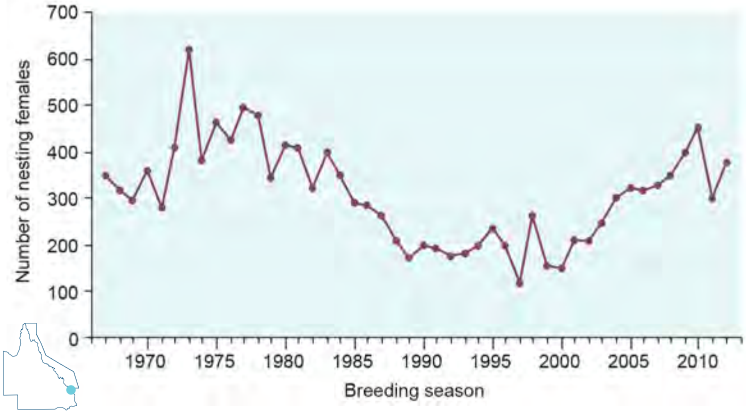

Figure 2.12 Trends in loggerhead turtle nesting, Woongarra coast, 1967–2012
After a gradual decline in the loggerhead turtle nesting populations on the Woongarra coast, including Mon Repos Beach–a key nesting site for turtles that inhabit the Region–there is now evidence of recovery. Data for 1967 and 1968 are population estimates. Other data is derived from population census. Source: Limpus *et al.* 2008[6] and Limpus (personal communication)[218]

Milman Island, in the northern Great Barrier Reef, is the primary index nesting site for Torres Strait–northern Great Barrier Reef stock of hawksbill turtles. A ten-year study on Milman Island indicated an annual rate of decline of three per cent in the nesting population.[216] A later study of foraging animals inhabiting the Howick group of islands, also in the northern Great Barrier Reef and within the same hawksbill turtle stock, found a similar decline between the late 1990s and the late 2000s, with some stabilisation between 2003 and 2008.[217]

Wreck, Erskine and Tryon islands in the Capricorn group of islands and the Woongarra coast, just south of the Region, are key nesting locations for the eastern Australian loggerhead turtle stock. This stock continues to recover after declining by more than 80 per cent between 1970 and the early 2000s (Figure 2.12).[6] Threats outside the Region may be affecting juvenile recruitment into the foraging population.[6]

Key nesting locations for the eastern Australian flatback turtle stock are Peak, Wild Duck and Avoid islands in the southern Great Barrier Reef. There has been no obvious trend in the size of the annual nesting population at these rookeries over three decades and the population is considered to be stable.[209] However, there is no new published data since Outlook Report 2009 and there continues to be virtually no data on the foraging population.[209]

A very small number of leatherback turtles are known to have nested on mainland beaches adjacent to the Region but no nesting has been recorded since 1996. The Region's population is considered to be part of the south-west Pacific genetic stock, which has declined.[219]

There is no nesting of olive ridley turtles in the Region and there is virtually no data on the foraging animals that visit the Region.[220]

For those marine turtle species that migrate outside the Region, there is a poor understanding of their activities and the impacts on them in those other places.

2.4.12 Estuarine crocodiles

The estuarine crocodile population continues to recover steadily.

Estuarine crocodiles occur in most coastal waters of the Great Barrier Reef. They are also regularly reported at mid-shelf and some offshore islands.[221] Although crocodiles once were extensively commercially harvested, their numbers in northern Queensland are now recovering following full protection under Queensland legislation since 1974.[221] The most recent surveys conducted in 2009–10 in the southern two-thirds of the Region showed the population continues to steadily recover, with no southerly expansion of its range.[222] The species' recovery is limited primarily by the availability of suitable nesting habitat.[223]

2.4.13 Seabirds

Trends in seabird populations are highly variable between different species and locations.

Islands and cays within the Great Barrier Reef support breeding populations of 20 seabird species.[26] It is estimated that between 1.4 and 1.7 million seabirds breed throughout the Great Barrier Reef each year.[224] This represents more than 25 per cent of Australia's tropical seabirds, more than 50 per cent of offshore–foraging black noddies and approximately 25 per cent of wedge-tailed shearwaters, brown and masked boobies and red-tailed tropic birds.[224] The number of non-breeding birds (birds which use the Region for feeding but breed elsewhere) is estimated to be about 425,000, giving a total seabird population that may exceed two million.[206] The global importance of the Reef's seabird populations contributes to its outstanding universal value[23].

In terms of variety of species, numbers of breeding adults and conservation significance, the four most important seabird areas in the Great Barrier Reef are Raine Island[225], Michaelmas Cay[226], the islands of the Capricorn–Bunker Group[227] and the cays of the Swain Reefs.[228] While there is regular monitoring at many of these sites[229], long-term trend information is only available for a small number of islands, such as Michaelmas Cay, and for only a limited number of species. Fourteen seabird species regularly breed at Raine Island in the Region's north making it one of the most important seabird rookeries in the Region.[26] Information presented in the Outlook Report 2009 suggested there were declines in many seabird species at Raine Island; however, a review of the survey method and recent survey data indicate declines may not be evident in all species.[230] Surveys of Raine Island conducted in July 2013 recorded the highest numbers of breeding pairs of lesser frigatebirds since surveys began in 1979.[230]

There are declines in some seabird breeding areas and changes in key supporting resources.

Monitoring at Michaelmas Cay shows wide annual variation in seabird breeding numbers. It suggests there have been no significant long-term trends in the island's breeding populations of common noddies, crested terns and sooty terns over the past 30 years (Figure 2.13).

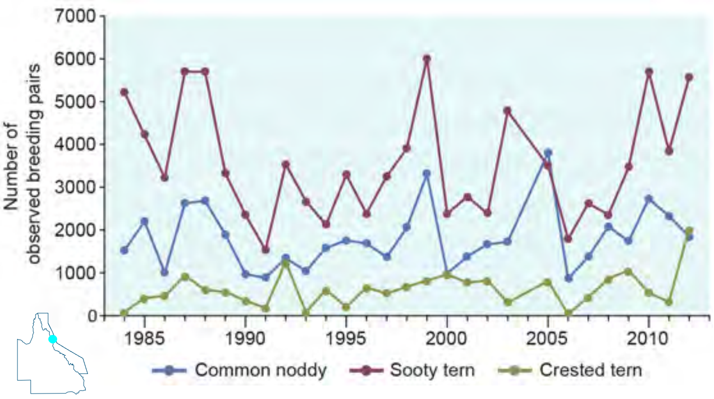

Figure 2.13 Mean number of observed seabird breeding pairs, Michaelmas Cay, 1984–2012

The number of seabirds breeding on Michaelmas Cay varies from year to year. There are no clear long-term trends. The data represents the average number of breeding pairs recorded during field observations of three seabird species: the common noddy, sooty tern and crested tern. Source: Queensland Coastal Bird Atlas 2014[231]

Monitoring data collected from islands in the Capricorn–Bunker Group indicate the wedge-tailed shearwater population may have declined by nearly 40 per cent over the past 15 years while black noddy numbers have remained relatively steady.[232] Despite a ten-year gap in the monitoring effort and limited recent surveys, these trends are cause for concern in the context of associated declines in New Caledonia[232] and likely changes in key supporting resources and environmental conditions[232] as a result of factors such as climate change[233,234].

The population of the brown booby nesting in the Swain Reefs may have declined between the 1980s and the 1990s as vegetation was lost from key breeding cays, principally from a series of cyclones in the area, and the habitat has only partially recovered.[228,235] Gannet Cay (named for the boobies breeding on it) was a very important breeding island in the Swain Reefs and a sharp decline in breeding pairs was observed following almost complete vegetation loss in the mid-1980s[228] (Figure 2.14).

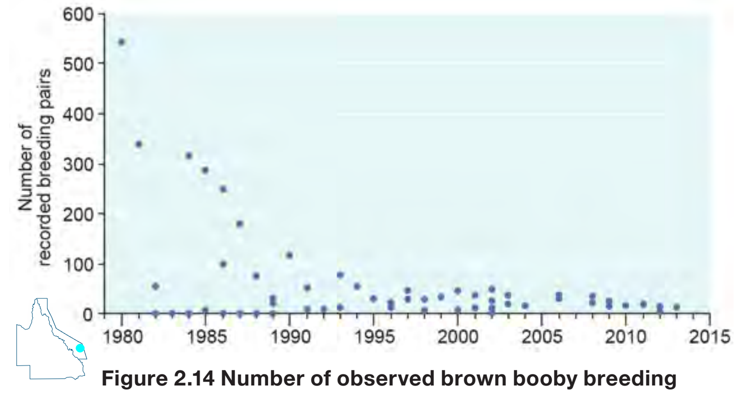

Figure 2.14 Number of observed brown booby breeding pairs, Gannet Cay, 1980–2013

The data represents the number of breeding pairs recorded during field observations. The number of brown boobies breeding at Gannet Cay in the Swain Reefs declined following the almost complete loss of vegetation in the mid-1980s. Source: Queensland Coastal Bird Atlas 2014[231]

2.4.14 Shorebirds

At least 41 species of shorebirds are known to inhabit the Great Barrier Reef.[236] A number of sites are known to provide important habitats for shorebirds, including the islands off False Orford Ness in Cape York, Pelican Island and nearby islands, Cairns foreshore, Cape Bowling Green, Burdekin River delta, Pioneer River to McEwan's Beach and Notch Point near Mackay, Shoalwater Bay and Broad Sound.[237]

There are no population estimates for the Region's shorebirds. Australia-wide declines of between 70 and 80 per cent have been recorded in the past 24 years[238], including populations that migrate through the Region.

2.4.15 Whales

It is estimated that 15 species of whale inhabit the Region, either seasonally or throughout the year, and there is limited information on the condition of most of these, with the exception of the humpback whale and the dwarf minke whale.[239]

Brown booby and chick, Raine Island

There is little information on the condition of most whale populations; humpback whales are recovering strongly.

The humpback whale is a listed threatened species which has been monitored since the 1980s. Its population is continuing to recover strongly after being decimated by whaling which stopped in the 1960s (Section 2.2.1). From an east Australian population as low as 500 animals when whaling ceased, numbers have grown consistently with an estimated annual recovery rate of between 10.5 and 12.3 per cent.[240] The population was estimated to be more than 10,000 animals in 2007[240] — about half of the estimated pre-whaling population size.[240] The most recent 2010 survey provides no evidence that the rate of population growth is slowing significantly with an absolute population abundance in that year of over 14,500.[241]

Dwarf minke whales visit the northern Region each winter — the only location in the world with predictable encounters with these whales. Dwarf minke whales are also reported in very low numbers further south in the Region.[242] Being a relatively cryptic species, little is known of the population status of dwarf minke whales that migrate there. The population of dwarf minke whales that interact with visitors in the Region has been conservatively estimated to be 449 in 2006, 342 in 2007 and 789 in 2008.[243] It is unknown whether this reflects actual abundance or only that part of the population that is more likely to interact.[244]

Dwarf minke whales visit the Region each winter © Matt Curnock

2.4.16 Dolphins

There is estimated to be 18 species of dolphin in the Region. They are found throughout the Region with some species solely inhabiting inshore waters and others typically being found far from the coast. There is limited information or monitoring of the status of most species.

While all dolphin species are protected in the Region, the Australian snubfin and Indo-Pacific humpback dolphins are considered the highest priority for management in the Region because of their small, localised populations, exposure to high levels of human activity, and suspected population declines.[245] Recent research suggests the northern Australian population of Indo-Pacific humpback dolphin that occurs in the Region may be a distinct species.[246] This new classification would have implications for its conservation status as the population would be smaller and more confined than under its current classification.

Two inshore dolphin species are considered at risk and likely to be in serious decline.

There are no overall population estimates for the Australian snubfin or Indo-Pacific humpback dolphins in the Region.[247] At a local scale, it is estimated that there are less than 100 Australian snubfin dolphins in Cleveland–Halifax Bays[248] and about 70 in Keppel Bay–Fitzroy River[249]. An aggregation has also been recorded at Princess Charlotte Bay–Bathurst Bay on Cape York Peninsula[250], but there has been no population census. There have been population estimates for Indo-Pacific humpback dolphins in Cleveland Bay (50 or less)[248]; the Capricorn coast (about 64); Keppel Bay (about 107); and Port Curtis (about 85)[251]. Populations of this species are also known to occur south of the Region in Great Sandy Strait[252] and Moreton Bay[253]. There is almost no understanding of populations of these two species elsewhere in the Region, although there have been sightings.

Populations of these inshore species are likely to be in decline throughout the Region. For populations to remain stable, modelling suggests that the snubfin dolphin population in Cleveland–Halifax Bays and Keppel Bay–Fitzroy River can sustain a human-related death rate of only one animal every four years[254] and one animal every year respectively.[249] The incidental deaths of two snubfin dolphins in Halifax Bay in 2011 and another in 2013 means the long-term viability of this population is at risk. There are similar concerns for Indo-Pacific humpback dolphins in Keppel Bay and Port Curtis where eight died of unknown causes in 2011.[211] It is likely that changes in the population's size will not be detectable over a short time period, unless they are very high (greater than 20 per cent per year). This could mean local populations of the two species could decrease to very low levels before a decline is detected.[248]

Another inshore species, the Indo-Pacific bottlenose dolphin, has similar life history traits to the Australian snubfin and Indo-Pacific humpback dolphins.[255,256] However, the Indo-Pacific bottlenose dolphin uses a wider range of habitats and may be more abundant,[255,256,257,258] though there is limited information on the population status within the Region.

The other 15 dolphin species in the Region are likely to be less susceptible to pressure. They generally occur further offshore and have less conservative life history traits. For example, the common bottlenose dolphin usually associate in large groups, display low site fidelity, and forage on large prey aggregations. Many of the species are rarely seen or only intermittently reported as stranded.[259]

While the northern dugong population remains stable, the population south of Cooktown has declined substantially.

2.4.17 Dugongs

The Region is home to a globally significant population of dugongs and provides essential habitat and connectivity between populations in the Torres Strait and the waters off south-east Queensland.[260] The Region's population is recognised as contributing to its outstanding universal value.[23]

Monitoring of dugong populations in the Region began in 1985 (Figure 2.15). The dugong population in northern areas of the Region is considered in good condition and stable with no evidence of a major decline.[261,262,263,264]

The southern, or urban coast, dugong population (south of Cooktown) has declined over many decades. Modelling indicates this occurred at an average rate of 8.7 per cent per year between 1962 and 1999, with most of the decline occurring in the early years.[268] The Outlook Report 2009 reported that the southern population was thought to have stabilised. However, indirect impacts of declining seagrass abundance (see Section 2.3.4 and Section 2.4.2) — the primary food resource for dugongs — combined with direct human-related impacts such as drowning in commercial fishing set mesh nets, boat strike, marine debris and illegal poaching has caused the southern dugong population to decline again.[267,269]

In 2011, there was an estimated population of only 600 animals between the Daintree River and the Region's southern boundary[3,267], compared with an estimate of around 2000 from the previous survey in 2005[267,270]. This estimate is a standardised relative index of dugong abundance and is less than the actual abundance. This is the lowest population estimate for this area since surveys began in 1987[267] and coincided with significant seagrass losses (Section 2.3.4). The decline is likely to be explained by animals moving out of the survey area to seagrass meadows elsewhere and increased mortality.[266,267] In 2011, an unprecedented number of stranded dugongs were found, reported and verified along the Region's coast (Figure 2.16).

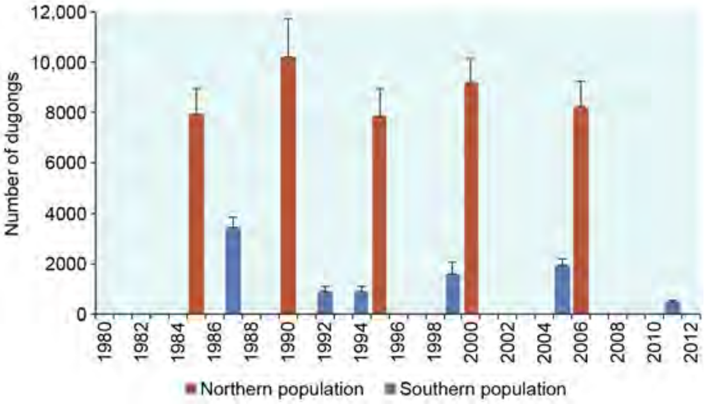

Figure 2.15 Dugong populations, 1985–2011
In 2009, the Region's southern dugong population was thought to have stabilised after a long history of decline. However, recent surveys indicate further decline, principally as a result of deterioration in seagrass meadows. Surveys indicate the population north of Cooktown is stable. Some of the variation between surveys is due to animals moving between and within survey regions. The error bars represent standard error. Source: Marsh *et al.* (various years)[3,262,264,265,266] and Sobtzick *et al.* 2012[267]

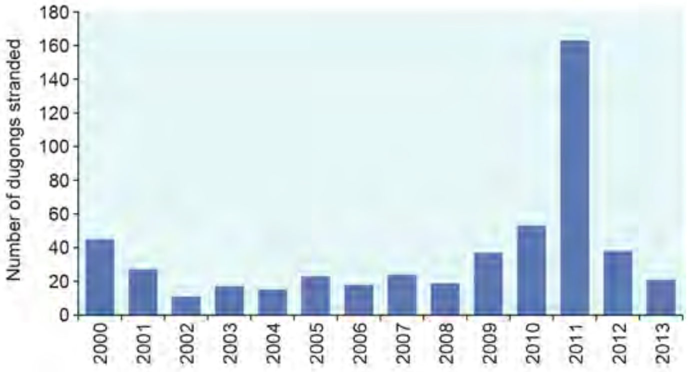

Figure 2.16 Dugong strandings, 2000–2013
There was a pronounced increase in stranded dugongs along the Region's coast in 2011, principally as a result of declines in seagrass meadows — their main source of food. The graph represents the number of sick, injured, or dead dugongs that have been found, reported and verified and hence it generally is only for the urban coast south of Cooktown. Only cases confirmed in the field by a trained person and later verified by an expert are graphed. Source: Department of Environment and Heritage Protection (Qld)[213] and Department of Agriculture, Forestry and Fisheries (Qld) unpublished data[214]

2.5 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.

2.5.1 Habitats to support species

Outlook Report 2009: Assessment summary
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.

2009 Grade	Current summary and assessment components	Assessment grade and trend				Confidence	
		Very good	Good	Poor	Very poor	Grade	Trend
🟦	**Habitats to support species:** Information on the condition and trend of habitats is highly variable with some well known (for example shallower coral reefs) and others poorly known, particularly habitats in remote areas or deep waters (for example Halimeda banks). The habitats of the northern third of the Region are believed to remain in very good condition and are able to support dependent species. Habitats in the southern two-thirds of the Region — especially those inshore — have deteriorated, particularly seagrass meadows and coral reefs.		↓				
🟦	**Islands:** Some islands have been affected by recent extreme weather, invasive pests and weeds, marine debris, climate change and coastal development.		↓			◐	◐
🟦	**Mainland beaches and coastlines:** Some mainland beaches and coastlines have been modified especially around urban centres and ports. However most remain in a relatively natural state.		↔			◐	◐
🟦	**Mangrove forests:** Mangrove forests remain relatively stable and abundance is being maintained.		↔			◐	◐
🟦	**Seagrass meadows:** Many inshore seagrass meadows have declined since 2009, especially due to extreme weather events. Some meadows have shown early signs of recovery.			↓		◐	◐
🟦	**Coral reefs:** A series of disturbances has reduced coral cover in the southern two-thirds of the Region. Some areas are not yet showing signs of recovery. There are few indications of recent damage to deeper reefs.			↓		●	●
🟦	**Lagoon floor:** Recent reductions in trawling effort and better management have reduced the area of lagoon floor being affected by the fishery. There is likely to be localised damage from dredging, disposal of dredge material and anchoring.		↔			○	○
🟦	**Shoals:** There is limited information about shoals. They are likely to be impacted by fishing and anchoring activities.		↔			◐	○
🟦	**Halimeda banks:** There is limited information about Halimeda banks. Given the habitat is remote and in deep water it is isolated from land-based impacts and is likely to be undisturbed.	↔				○	○

2.5.1 Habitats to support species *continued*

2009 Grade	Current summary and assessment components	Assessment grade and trend				Confidence	
		Very good	Good	Poor	Very poor	Grade	Trend
🟦	**Continental slope:** Much of the continental slope remains undisturbed and minimally impacted by human activities. In the south-east, an area is at high ecological risk because of sustained high levels of trawling.		↓			○	○
🔷	**Open waters:** Inshore open water habitats are degraded in the southern two-thirds of the Region principally due to pollutants from land-based run-off. This habitat is thought to be minimally impacted in the remainder of the Region.		↓			●	●

Grading statements

🟦 **Very good**	🔷 **Good**	🟩 **Poor**	🟫 **Very poor**
All major habitats are essentially structurally and functionally intact and able to support all dependent species.	There is some habitat loss, degradation or alteration in some small areas, leading to minimal degradation but no persistent, substantial effects on populations of dependent species.	Habitat loss, degradation or alteration has occurred in a number of areas leading to persistent substantial effects on populations of some dependent species.	There is widespread habitat loss, degradation or alteration leading to persistent, substantial effects on many populations of dependent species.

Trend since 2009

↑ Improved
↔ Stable
↓ Deteriorated
— No consistent trend

Confidence

● Adequate high-quality evidence and high level of consensus
◐ Limited evidence or limited consensus
○ Inferred, very limited evidence

2.5.2 Populations of species and groups of species

Outlook Report 2009: Assessment summary

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 sharks, 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.

2009 Grade	Current summary and assessment components	Assessment grade and trend				Confidence	
🔷	**Population of species and groups of species:** There is condition and trend information for only a limited number of species and species groups; hence the assessment of some components is highly uncertain. Of those for which there is information, there have been significant declines in many, especially in the inshore southern two-thirds of the Region, and some iconic and cultural keystone species. For example, significant declines have been recorded in most hard corals and seagrasses, some fishes and sharks, dugongs, plus some seabird populations. There are four examples of species showing good recovery after past serious declines: humpback whales, estuarine crocodiles, loggerhead turtles and green turtles (southern stock). However, even these species have not recovered to their original numbers. The overall condition of the Region's species appears to have deteriorated significantly and the assessment of 'good' is considered borderline with 'poor'.		↓				
		Very good	Good	Poor	Very poor	Grade	Trend
🟦	**Mangroves:** The diversity and abundance of mangrove species are being maintained.	↔				◐	○
🔷	**Seagrasses:** Seagrass abundance has declined and community composition has changed in central and southern inshore areas, mainly due to cyclones, flood events and extended periods of cloud cover, in addition to the longer term impacts of poor water quality. There is limited information on deep-water seagrasses.			↓		◐	◐
🔷	**Macroalgae:** The diversity of macroalgae is being maintained and abundance has increased in some areas. Macroalgae is likely to have benefited from elevated levels of nutrients associated with human activity and increases in available habitat after cyclones.		↔			◐	◐
🟦	**Benthic microalgae:** There is limited information about benthic microalgae. They are likely to have benefited from elevated nutrients and experienced some disturbances.	↓				○	○
🔷	**Corals:** Hard coral abundance has substantially decreased in the southern two-thirds of the Region. Soft coral cover in inshore areas is generally stable with some declines after severe cyclones and flooding. The community composition of inshore coral reefs has changed over the past century.			↓		●	●

2.5.2 Populations of species and groups of species *continued*

2009 Grade	Current summary and assessment components	Assessment grade and trend				Confidence	
		Very good	Good	Poor	Very poor	Grade	Trend
🟦	**Other invertebrates:** Little is known about most invertebrates. Changing environmental conditions in central and southern inshore areas, as well as some fishing activity, are likely to have affected invertebrates. Human-related impacts are implicated in outbreaks of crown-of-thorns starfish.		↓			○	○
🟦	**Plankton and microbes:** Changes in water temperature and quality are likely to be altering plankton communities.	↓				○	○
🔷	**Bony fishes:** Little is known about the condition of most fish species; habitat declines are likely to have negatively affected them. The abundance of some fished species has declined. Fishing activities affect targeted and non-targeted species.		↓			◐	◐
🟩	**Sharks and rays:** The condition of most shark and ray species is unknown. Many are considered at risk. One species of shark is likely to be near extinction or extinct in the Region.			↓		◐	◐
🟩	**Sea snakes:** A large number of sea snakes are caught as bycatch. Reduction in effort and better management of trawl fisheries is likely to have reduced impacts on some sea snakes.			↔		◐	○
🟩	**Marine turtles:** Nesting populations of most marine turtle populations are stable or increasing. Some are in decline and all are conservation dependent. Turtle populations are affected by threats both within and well beyond the Region.			–		●	●
🔷	**Estuarine crocodiles:** The estuarine crocodile population continues to recover steadily after being protected under Queensland legislation in 1974. Recovery is limited primarily by the availability of nesting habitat.		↑			◐	●
🟩	**Seabirds:** Trends in seabird populations are highly variable between different species and locations, and there are limited long-term data. Changes in key supporting resources and environmental conditions are affecting some seabirds.			–		◐	◐
Not assesed	**Shorebirds:** There are no population estimates for the Region's shorebirds; there are substantial declines Australia-wide, including for migratory populations that would move through the Region.			🟩		○	
🔷	**Whales:** There is little information on the condition of most whale populations; humpback whales are recovering strongly.		↑			◐	◐
🔷	**Dolphins:** Two inshore dolphin species are considered at risk and likely to be in serious decline. The inshore bottlenose dolphin is also considered vulnerable. There is limited information available on trends in the other 15 dolphin species but they are likely to be less susceptible to pressure.		↓			○	○
🟩	**Dugongs:** While the northern dugong population remains stable, the population south of Cooktown has declined substantially due to a combination of extreme weather and human-related impacts.			↓		●	●

Grading statements

🟦	**Very good** Only a few, if any, species populations have deteriorated as a result of human activities or declining environmental conditions.
🔷	**Good** Populations of some species (but no species groups) have deteriorated significantly as a result of human activities or declining environmental conditions.
🟩	**Poor** Populations of many species or some species groups have deteriorated significantly as a result of human activities or declining environmental conditions.
▩	**Very poor** Populations of a large number of species have deteriorated significantly.

Trend since 2009

↑	Improved
↔	Stable
↓	Deteriorated
–	No consistent trend

Confidence

●	Adequate high-quality evidence and high level of consensus
◐	Limited evidence or limited consensus
○	Inferred, very limited evidence

2.5.3 Overall summary of biodiversity

The Great Barrier Reef remains one of the world's most unique and biologically diverse ecosystems. At the scale of the whole Region, the majority of its habitats are assessed to be in good to very good condition, however an increasing number are assessed as being in poor condition. This includes the two key habitats of coral reefs and seagrass meadows in the southern two-thirds of the Region. The condition of a number of species has deteriorated since the assessment in the Outlook Report 2009, with some important species now assessed as being in poor condition.

On a regional scale, the habitats and species north of the Port Douglas–Cooktown area are in better condition than those further south. Also, habitats further offshore and in deeper water are typically subject to fewer threats and are therefore presumed to be in better condition, including the lagoon floor, shoals, Halimeda banks, deeper reefs and the continental slope.

A range of past and current threats, including pollutants in land-based run-off, crown-of-thorns starfish outbreaks, death of discarded species, incidental catch of species of conservation concern and recent extreme weather, have caused declines in the biodiversity values of the southern two-thirds of the Region, especially in inshore and mid-shelf areas.

For some species, such as sharks and rays, corals, some marine turtles and dugongs their condition is assessed as poor and deteriorated. Two species of inshore dolphins are also considered at high risk and in decline.

There are few examples of recovering populations. Those that are recovering are species that declined as a result of human-related impacts which are now eliminated or reduced, for example commercial whaling for humpback whales and incidental drowning of marine turtles in trawl nets. These populations have yet to recover to their original size and, as they tend to be long-lived species, full recovery is likely to take decades.

Biodiversity is critical to the outstanding universal value of the world heritage property. While both criteria are assessed as being in good condition, the current trends for 14 of the 27 components are assessed as deteriorated since 2009. This has meant that the grade of 'good' is borderline with 'poor' and is likely to deteriorate further in the future.

A lack of comprehensive information means the assessment of many habitats and species or groups of species is principally based on limited evidence and anecdotal information. Understanding of the less accessible habitats, such as the lagoon floor and continental slope, is poor and often based on one-off surveys — there is little or no trend information. Key gaps in knowledge include understanding of deeper reefs and deep-water seagrass meadows, islands, and identification of new biodiversity hotspots. Biological and ecological information is lacking on inshore dolphins and populations of seabirds that breed in the Great Barrier Reef as well as some targeted 'at risk' fishery species and populations of bycatch species. Sea snakes and some shark and ray populations are poorly understood as are turtle populations after migration out of the Marine Park.

The Great Barrier Reef remains one of the world's most diverse ecosystems © Matt Curnock

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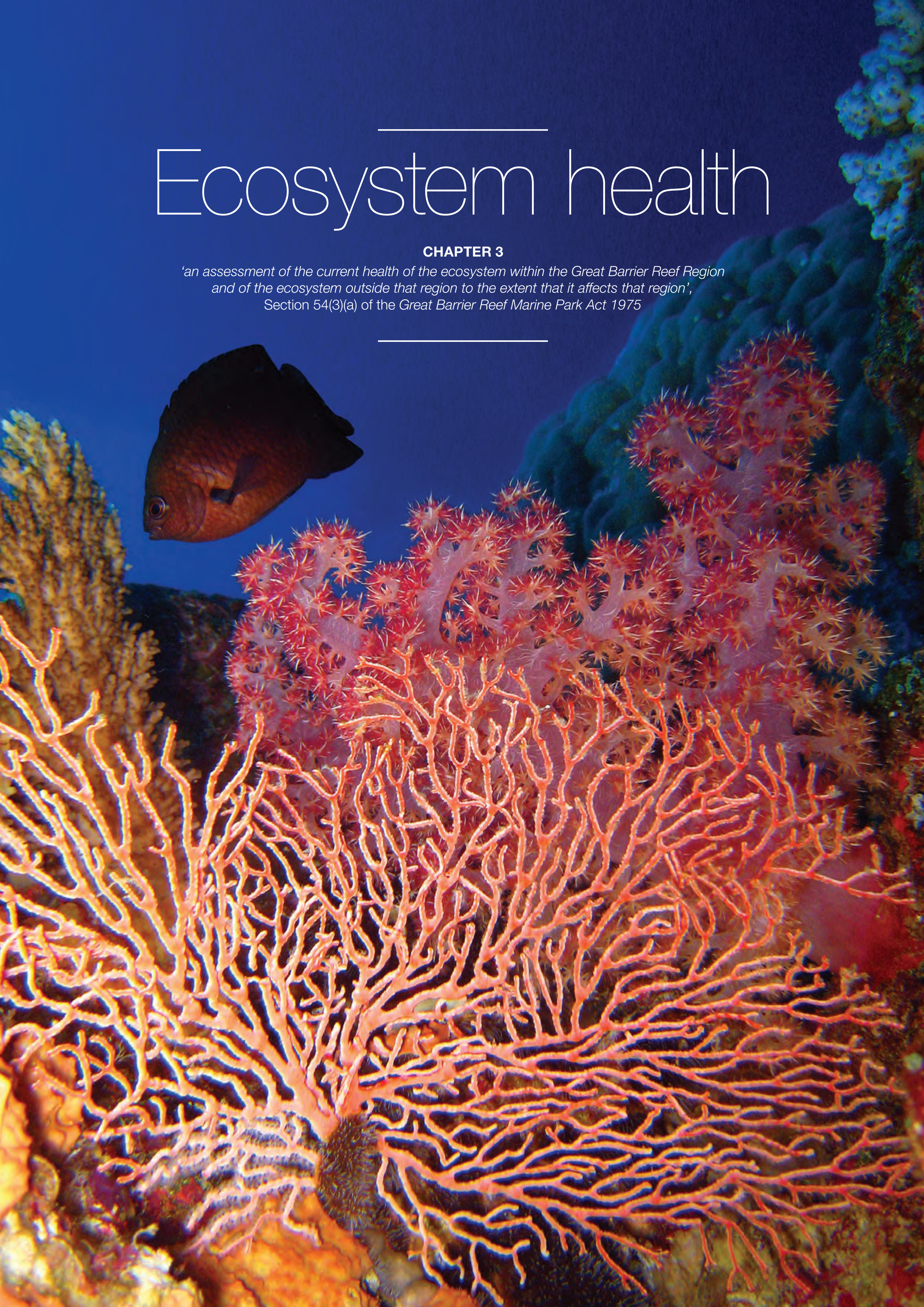
Ecosystem health

CHAPTER 3

'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*



2014 Summary of assessment

Physical processes	The condition of all physical processes has declined since 2009. Further changes in processes such as sea temperature, sea level, cyclones and wind, freshwater inflow, waves and currents are expected under climate change projections. Reduced sediment loads entering the Region are likely to improve the processes of sedimentation and light availability in the longer term.	↓ Good, Deteriorated
Chemical processes	Nutrient cycling in the Region continues to be affected by nutrients from land-based run-off but changes in land management are likely to result in long-term improvements. Heavy rainfall in recent years has temporarily affected ocean salinity in some parts of the Region. Ocean pH is changing and is projected to decline in the future under climate change scenarios. Unlike the Outlook Report 2009, this assessment does not include consideration of pesticide accumulation.	↓ Good, Deteriorated
Ecological processes	At a Reef-wide scale, most ecological processes are considered to be in good condition but significant losses in coral cover and declines in ecosystem health in the inshore, southern two-thirds of the Region are likely to have affected some key ecological processes such as connectivity, reef building and recruitment.	↓ Good, Deteriorated
Terrestrial habitats that support the Great Barrier Reef	Terrestrial habitats that support the Reef are generally in better condition in the northern catchment. However, supporting habitats have been substantially modified in southern areas (south of about Port Douglas), especially wetlands, forested floodplains, grass and sedgelands, woodlands and forests, and rainforests.	🟩 Poor, Trend not assessed
Outbreaks of disease, introduced species and pest species	Coral disease is being increasingly observed on the Great Barrier Reef and is predicted to increase in the future. There are few incidences of other disease and introduced species in the marine environment and they tend to be localised. Outbreaks may be becoming more frequent as ecosystem conditions decline. The overall assessment of 'poor' is due to the severity of outbreaks of crown-of-thorns starfish which seriously affect coral reef habitats on a large scale.	– Poor, No consistent trend

Full assessment summary: see Section 3.7

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Ecosystem health

3.1 Background

> **Outlook Report 2009:** 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 in 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.

As outlined in the *Great Barrier Reef Outlook Report 2009*[1], the notion of 'health' can be applied to both individual organisms and an ecosystem as a whole. An ecosystem is considered healthy if it is able to maintain its structure and function in the face of external pressures.[2]

In order to systematically assess the health of the Great Barrier Reef ecosystem, its main physical, chemical and ecological processes are considered (Figure 3.1).

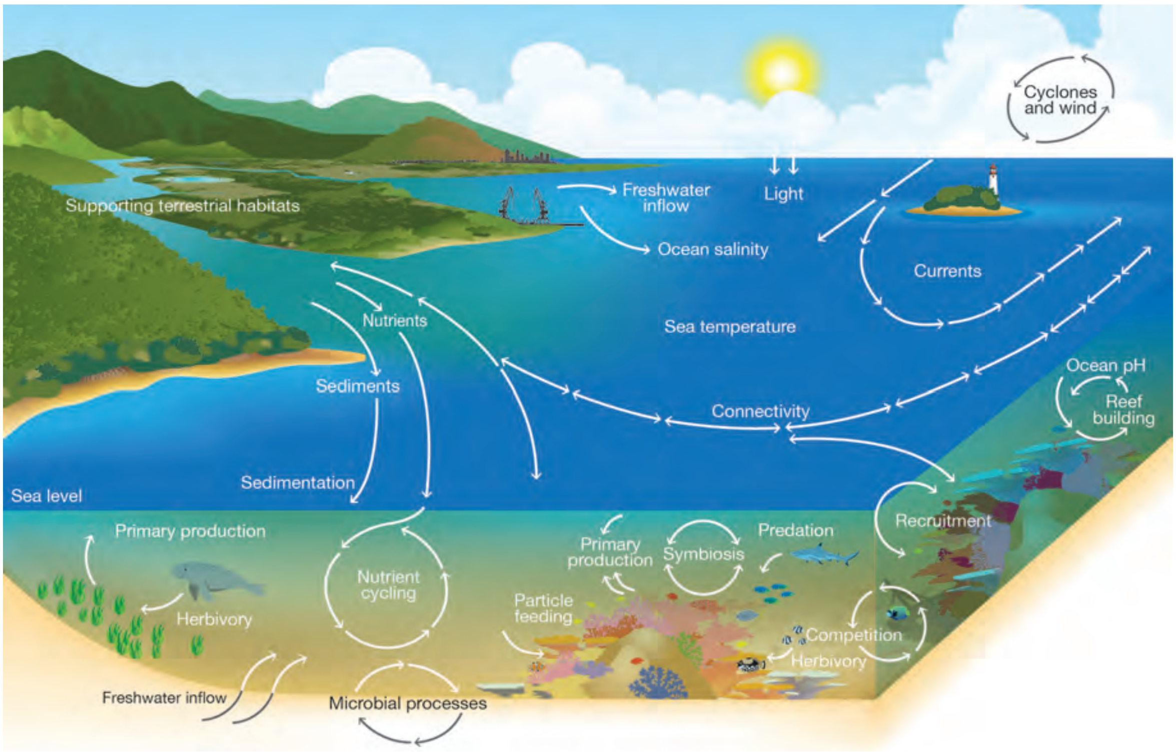


Figure 3.1 Major physical, chemical and ecological processes
The health of the Great Barrier Reef ecosystem is assessed by considering its physical, chemical and ecological processes as well as the condition of its supporting terrestrial habitats. Outbreaks of pests and diseases are also considered as a guide to overall health.

These processes are interconnected and the overall health of the ecosystem requires all to be in good condition. Many are important attributes recognised as contributing to the outstanding universal value of the Great Barrier Reef World Heritage Area (Appendix 3). The individual processes assessed have remained the same as those in the Outlook Report 2009, except the ecological process of recruitment has been included; and, recognising that it is not a natural process, consideration of pesticide accumulation has been relocated to Section 6.5.

An assessment of the condition of terrestrial habitats that support the Great Barrier Reef is also included in this Outlook Report. This recognises the important role of terrestrial habitats in the health of the Great Barrier Reef — from capturing nutrients and sediments to providing feeding and breeding areas for a range of species. As in the Outlook Report 2009, outbreaks of disease and introduced and pest species are examined as their frequency and severity are a gauge of overall ecosystem health.

3.2 Current condition and trends of physical processes

3.2.1 Currents

The Great Barrier Reef is part of a larger system of ocean circulation throughout the Pacific Ocean, which delivers nutrients and larvae from other regions as well as deep water into the Great Barrier Reef Region (the Region). Currents and upwellings are recognised as key ecological processes that contribute to the Reef's outstanding universal value.[3]

At the largest spatial scale (thousands of kilometres), major oceanic currents of the Coral Sea affect patterns of connectivity and the temperature of the Region's waters.[4] At very small scales (centimetres to metres) turbulence can affect the larval settlement patterns of a range of species such as corals.[4] While surface currents are primarily driven by wind, deeper ocean currents are mainly driven by relative densities of seawater, affected by salinity and temperature.[4]

Upwelling of cold, nutrient-rich waters to the sea surface creates 'hotspots' of marine primary production.[4] In the Great Barrier Reef, upwelling intrusions include those on the central Great Barrier Reef which are enhanced during consistently low winds.[5] During these conditions, the southward-flowing East Australian Current flows faster, lifting the thermocline closer to the surface, spilling cooler waters onto the shelf.[4,5,6]

There is evidence of intensified flow and accelerated warming in the East Australian Current.

The Outlook Report 2009 reported there was little information about any changes to ocean currents on the Great Barrier Reef.[1] Since then there has been increasing evidence of intensified flow and accelerated warming in the East Australian Current adjacent to the Region's southern coast (see Section 6.3.1).[7] This current is transporting greater volumes of warmer water southward, carrying larvae and juveniles with it.[8] There remains little information about the Hiri Current which moves north along the coast in northern Great Barrier Reef waters.[7,9,10]

3.2.2 Cyclones and wind

Cyclones regularly affect tropical marine and terrestrial habitats at regional and local scales. In addition to strong winds and rain, the powerful waves generated during cyclones can seriously damage habitats and landforms, particularly coral reefs and shorelines.[4,11,12,13] It is estimated that cyclone damage has been one of several factors in coral cover loss in the Region.[14]

Between 2005 and 2013, there were six category 3 or above cyclones that affected the Great Barrier Reef (Figure 3.2).[15,16]

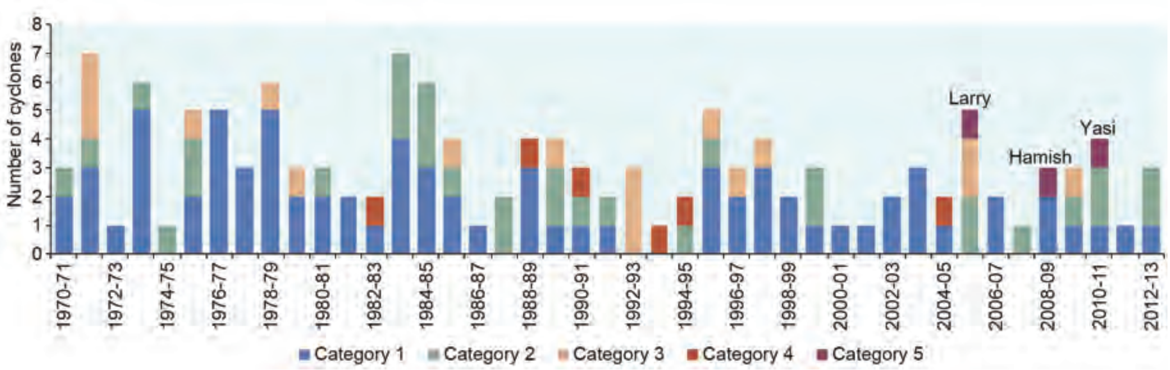
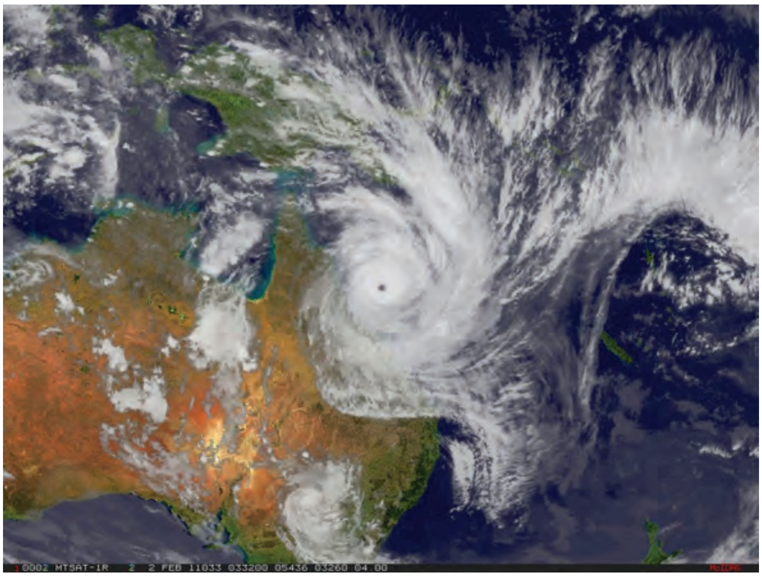


Figure 3.2 Number and severity of cyclones, 1970–2013
A number of severe cyclones have affected the Region over recent years. Source: Bureau of Meteorology[17]

Impacts on the ecosystem were most severe in the southern half of the Region, causing significant damage to coral reef habitats, particularly due to cyclone Hamish, in March 2009, which affected more than 50 per cent of the coral reefs in the Region.[15,16]

In February 2011, cyclone Yasi crossed the Queensland coast, one of the most powerful cyclones to have affected Queensland since records commenced.[18,19] Previous cyclones of a comparable intensity include the 1899 cyclone Mahina in Princess Charlotte Bay, and the two cyclones of 1918 at Mackay (January) and Innisfail (March). The damage from cyclone Yasi was extensive. Overall, some level of coral damage was reported in over 89,000 square kilometres of the Region. Approximately 15 per cent of the Region's total reef area sustained some coral damage and six per cent was severely damaged. Most of the damage occurred between Cairns and Townsville.[16] In April 2014, category 5 cyclone Ita entered the northern area of the Region, crossing the coast near Cape Flattery. The impacts of cyclone Ita were being assessed at the time of writing.



Category 5 cyclone Yasi affected much of the central Great Barrier Reef in February 2011
Source: Satellite image originally processed by the Bureau of Meteorology from the geostationary meteorological satellite MTSAT-2 operated by the Japan Meteorological Agency

Wind also plays a role in the marine ecosystem; in particular, it can cause substantial changes in the shape of islands and coastlines and can affect ocean currents.[4] There is emerging evidence of increases in wind strength Australia-wide, but little information specific to the Region.[20] Changes in wind patterns may have consequences for inshore ocean turbidity through resuspension of sediments[21]; island formation[22]; and the distribution of planktonic larvae[23]. Warming sea temperatures have implications for cyclones and wind (see Section 6.3.1).[24]

There is emerging evidence of increases in wind strength Australia-wide.

3.2.3 Freshwater inflow

The rivers and streams flowing into the Region drain an area of 424,000 square kilometres along the east coast of Queensland — the Great Barrier Reef catchment. There are six major natural resource management catchment regions: Cape York, Wet Tropics, Burdekin, Mackay Whitsundays, Fitzroy, and Burnett Mary. While the Wet Tropics rivers (from Ingham to about Port Douglas) deliver water to the Region almost all year, in other catchments there is little or no flow most of the time, interspersed with major floods usually during the summer monsoon season and on decadal timescales.[25]

In the Outlook Report 2009 it was reported that the flow of freshwater from 2004 to 2007 was significantly lower than the long-term average.[1] Since that time, increased annual rainfall and floods have resulted in much greater volumes of freshwater entering the Region (Figure 3.3). Between 2008 and 2012 higher than average annual freshwater discharges were recorded for many of the major rivers, especially in southern catchments.[26]

Large volumes of freshwater flowed into the Region in the past five years, including some record flows.

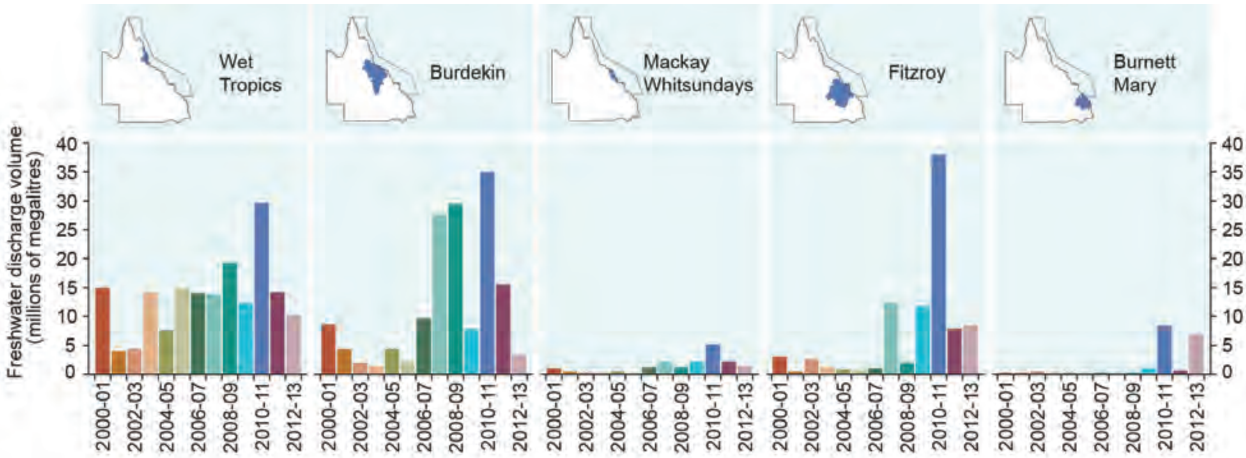


Figure 3.3 Annual freshwater discharge from major rivers, 2002–2013
Much greater volumes of freshwater entered the Great Barrier Reef lagoon between 2008 and 2012 compared to previous years. The annual discharges from the major rivers are combined for each natural resource management region. Each year is shown in a different colour and represents the discharge for the 12-month period starting in October. Source: Data supplied by Department of Natural Resources and Mines (Qld) compiled by the Australian Institute of Marine Science 2012[26] and McKenzie *et al.* 2014[33]

In 2011, discharge volumes in the Fitzroy and Proserpine rivers were the largest ever recorded.[26] In the Herbert River, the volume was equal to the biggest ever recorded, while the Burdekin River experienced the third biggest.[26]

Increased freshwater inflow to the Region during flood events carries with it pulses of nutrients, sediments, pesticides and other pollutants including marine debris, which have significant effects on inshore Great Barrier Reef habitats and species.[27]

Depending on the geology and soil permeability, freshwater also enters estuaries and the sea as groundwater.[28] Some mangroves, saltmarsh plants and seagrasses depend on freshwater seepage.[28] Some marine animals, for example sea snakes, consume freshwater from submarine groundwater seepages.[29] Freshwater also seeps through the ocean floor from drowned river channels called 'wonky holes'.[30] Wonky holes are considered important natural sources of nutrients for coral reefs[31] and seagrass meadows[32].

Changes to terrestrial habitats and infrastructure associated with development in the catchment are affecting the flow of water to the Region (see Section 6.4).

3.2.4 Sedimentation

Improved land management is beginning to reduce sediment input.

Sedimentation — the inflow, dispersion, resuspension and consolidation of sediments — has been a natural phenomenon in the Region since the current sea level was reached about 6500 years ago.[34,35,36] However, exposure of the Great Barrier Reef to terrestrial sediments and resuspended marine sediments has increased since European settlement of the adjacent catchment.[35,37,38] It is estimated that suspended sediment loads are now more than twice as high as before European settlement in the 1850s.[39,40] These increased loads affect sedimentation processes.

Modelling of pre-European exposure to suspended sediment suggests that its effects were concentrated very close to the coast around river mouths, with the largest plume adjacent to the Burdekin River.[34] Modelling for the years 2007 to 2011 indicates a vastly increased area of exposure (Figure 3.4). Inshore areas continue to be exposed to the most sediment, especially areas close to river mouths.[37,38]

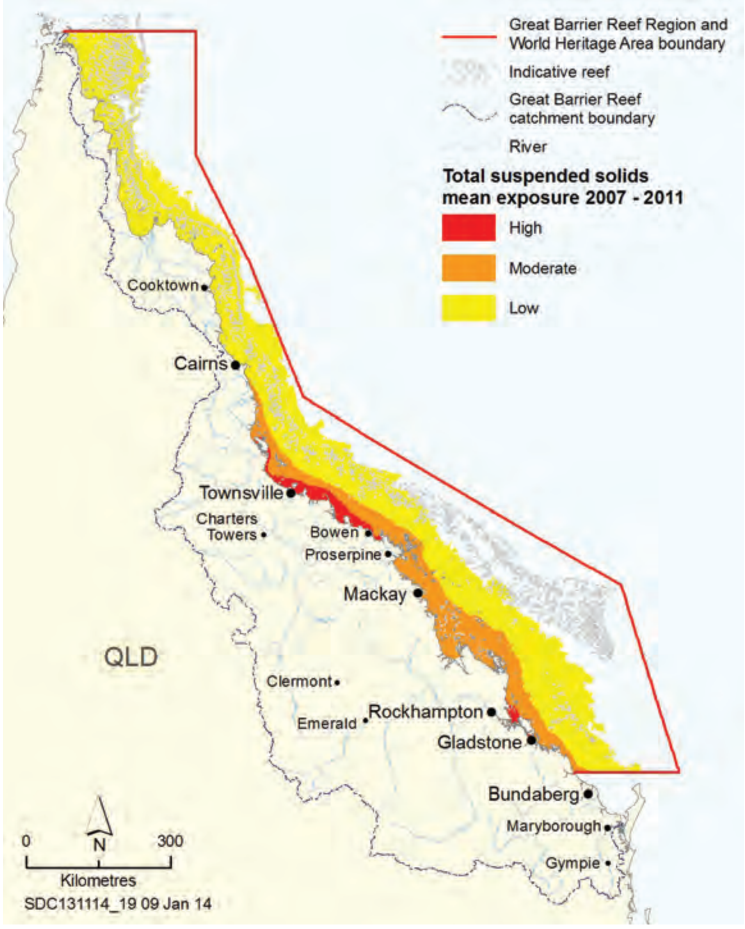


Figure 3.4 Exposure to suspended sediments, 2007–2011
The assessment classes (high, moderate and low) are relative and derived from a combination of scaled river load data and flood plume frequency analysis from remote sensing data. The mean of the five annual distributions was selected as a way of factoring in inter-annual variability in river discharge, although it is recognised that this period was characterised by several extreme rainfall events. Source: Brodie et al. 2013[60]

However, during flood events, suspended sediment may be carried long distances — as far as 100 kilometres northward for the Burdekin River plume in the 2010–11 wet season[41].

Longshore drift[41,42,43,44,45,46,47], tides and currents[4,48,49,50,51] widely redistribute sediment along the coast and across the continental shelf.[49,52,53,54,55] Possible increases in wind speed in the Region[20] are likely to cause more sediment resuspension in shallow water.[21]

Significant investments in land management practices from 2009 to 2013 have resulted in a modelled 11 per cent reduction in the average annual suspended sediment load delivered to the Great Barrier Reef.[56] However, there is likely to be a significant lag time before there are measurable and ecologically significant water quality improvements in the Region, with effects continuing for at least decades.[57]

Activities within the Region that contribute to increased sedimentation and resuspension plumes include anchoring and vessel wash from shipping, dredging, and disposal of dredge material. Recent modelling suggests resuspended sediment could potentially travel considerably further than previously understood.[58,59]

3.2.5 Sea level

Sea level is an important determinant of species and habitat distribution and affects foraging and reproduction activities of many species.[61,62,63] It varies naturally day to day with the tides and over longer time scales with the El Niño–Southern Oscillation.

In addition, cyclonic winds can cause storm surges — onshore rises of water above the predicted tide.[64]

Over the past 100,000 years sea levels have risen and fallen many times, shifting the position of reef growth on the continental shelf.[65] The role of sea level in the geomorphological evolution of the Great Barrier Reef is recognised in its world heritage listing.[3]

The fastest rates of sea level rise in Australian waters are in northern areas.

Sea level is rising in Australian waters, with the fastest rises being recorded in northern areas.[64,66] In the Region, sea level is rising by an average of about 3.1 millimetres per year.[64,67,68] Sea level data presented in the Outlook Report 2009 showed the Townsville area had experienced an average increase of 1.2 millimetres per year between 1959 and 2007 and the rate may be increasing. Since then, the rate of increase has accelerated, peaking in 2010 at 125 millimetres above the long-term (1959–2012) average (Figure 3.5).[69] Sea level at Townsville has now risen an average of 2.6 millimetres per year from 1959 to 2012 and an average of 11.8 millimetres per year between 2007 and 2012.[69]

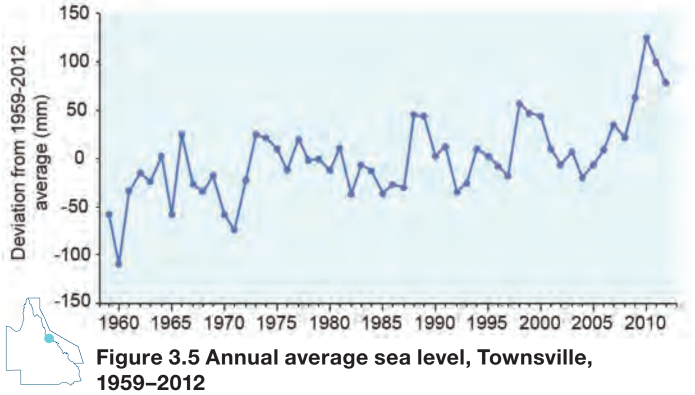


Figure 3.5 Annual average sea level, Townsville, 1959–2012
From 1959 to 2012 sea level in Townsville has varied 235 millimetres around the average for that period. Since the 1980s, the deviation from the average sea level has tended to be above the average. Source: Permanent Service for Mean Sea Level 2013[69]

Most reefs in the Region will probably be able to accommodate the current rate of sea level increase as the maximum rate of reef growth is about twice this.[70] However, sea level rise is predicted to increase at a higher rate (see Section 6.3.1) and coral reef growth may not be able to keep pace.[71] The shape and existence of some coastlines, cays and islands may also be affected.[22,72]

Even modest rises in sea level may have substantial consequences for other aspects of the Region, especially when combined with natural variability arising from the El Niño–Southern Oscillation. For example, the ability of marine turtles to nest and the survival of their eggs may be reduced if islands are inundated.[72]

3.2.6 Sea temperature

Sea temperature is a key environmental factor controlling the distribution and diversity of marine life.[73] It is critical to reef building and is one of the key variables that determine coral reef diversity and the north-south limits of coral reefs.[74] The average sea surface temperature in the Coral Sea has risen substantially over the past century. Since instrumental records began, 15 of the 20 warmest years have been in the past 20 years[75] (Figure 3.6 and see Section 6.3.1).

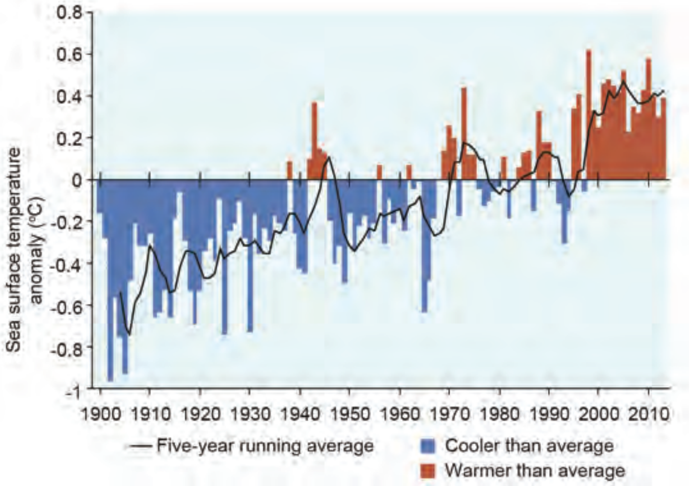


Figure 3.6 Sea surface temperature anomalies for the Coral Sea, 1900–2013
The hottest five-year running averages of sea surface temperature have all been in the last 15 years. This graph uses the 1961 to 1990 average as a baseline for depicting change. Source: Bureau of Meteorology 2014[82]

When temperature limits are exceeded, physiological processes may break down.[75,76] For reef habitats, the most critical mechanism affected is the symbiotic association between animals (such as corals and clams) and the microscopic algae which live within their tissues and provide much of their nutrition through photosynthesis. If sea temperatures exceed a certain threshold these algae are expelled — an effect known as bleaching.[77]

The ocean has warmed substantially over the last century, with most of the warmest years in the past two decades.

Severe bleaching events are linked to climate phenomena such as El Niño–Southern Oscillation which results in sustained elevated regional temperatures. At least nine mass bleaching events have affected the world's reefs since 1979. The Great Barrier Reef was most severely affected by the 1998 and 2002 events[78,79] but was also affected by bleaching in 2006.[79]

In the Region, the combination of other environmental variables such as cloud cover[80] and wind[81] have meant recent periods of elevated sea temperature have not been as prolonged as those of the late 1990s and early 2000s and have not resulted in widespread coral bleaching.

Sea temperature plays a role in ocean circulation as cooler, denser water sinks to the bottom and warmer, less dense water rises.[75] It also provides additional energy to the formation of tropical cyclones.[24]

3.2.7 Light

The availability of light is central to the health and productivity of seagrasses and other plants as well as the symbiotic relationship between some animals (for example corals and clams) and algae. Levels of available light control the depth range of marine plants (for example, seagrasses[83] and algae) as well as animals which rely on photosynthesis through symbiosis with plants.[84]

The rate at which light decreases in the water column is determined by both depth and water turbidity.[85] As a result, light becomes limiting at shallower depths in inshore, more turbid areas compared to offshore habitats which have less turbid water. Turbidity is affected by a number of external factors, such as sediment becoming resuspended by wind[21], currents and tides[86]; nutrients from land-based run-off[85]; as well as activities within the Region such as anchoring[87], vessel wash[87], dredging and the resuspension of dredge material[88]. Nutrients from land-based run-off can increase the growth of phytoplankton resulting in a decrease in the ambient light levels.[85] Extended periods of cloud cover also reduce light availability for the ecosystem.[33]

Turbidity is very variable from year to year (Figure 3.7) and week to week (Figure 3.8). In recent years turbidity is likely to have increased due to extreme flooding and the resuspension of sediment associated with storms and cyclones.[89]

A comparison of secchi disc readings from the 1928–29 British Museum Expedition to Low Isles with more recent readings from nearby sites offshore from Cairns suggest a 50 per cent decline in mean water clarity,[90] although there was less data in the 1928–29 sample.

Land-based run-off strongly affects light availability, not only in inshore areas but can extend up to 80 kilometres from the coast.[91] Given the increased input of sediments since European settlement (Section 3.2.4), it can be assumed that light availability has decreased substantially in inshore areas in the southern two-thirds of the Region.[85]

It is likely that light availability has decreased substantially in the inshore areas of the southern two-thirds of the Region.

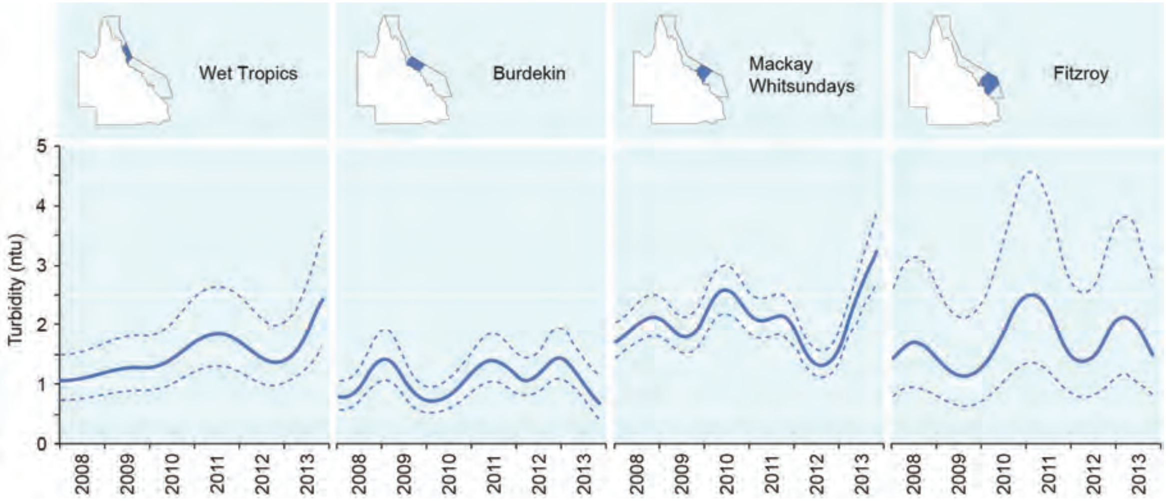


Figure 3.7 Regional trends in turbidity of inshore areas, 2008–2013
The solid line curves represent regional trends bounded by dashed lines depicting 95 per cent confidence intervals. (Data to October 2013). Data presented in graphs relate to turbidity levels in inshore areas of mapped regions above. Source: Thompson *et al.* 2014[92]

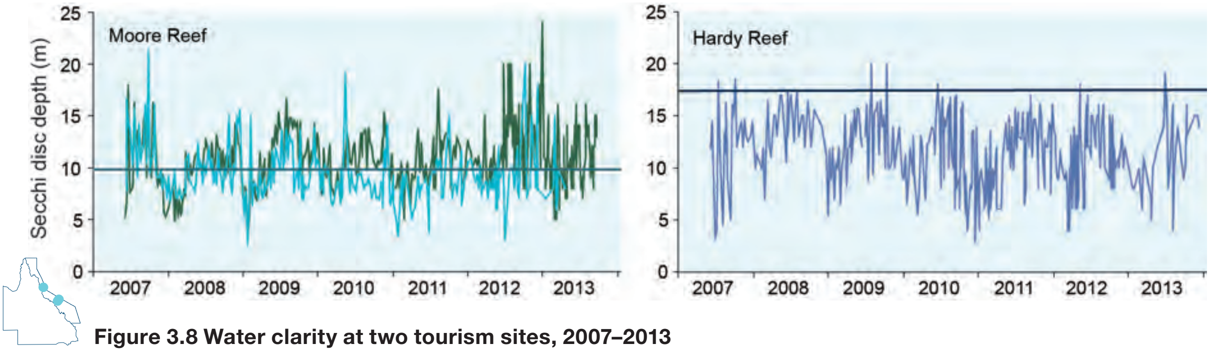


Figure 3.8 Water clarity at two tourism sites, 2007–2013
Clear water is a major motivation for people to visit the Reef. Secchi disc depth data collected voluntarily by tourism operators as part of the Great Barrier Reef Marine Park Authority's Eye on the Reef program from Moore Reef near Cairns (two operators), and Hardy Reef in the Whitsundays (one operator) provides an indicator of water clarity. The horizontal lines indicate the mean annual water quality trigger level for water clarity relevant to that site, based on the Water Quality Guidelines for the Great Barrier Reef Marine Park.[93] Source: Great Barrier Reef Marine Park Authority 2014[94]

3.3 Current condition and trends of chemical processes

3.3.1 Nutrient cycling

Nutrient cycling plays a critical role in maintaining ecosystem health. Most nutrient concentrations (for example nitrogen and phosphorus) in the open ocean are low.[95] Low concentrations of nitrates, in particular, severely limit plant productivity. Coral reefs farther naturally from land are able to survive in low nutrient waters by having a high level of nutrient cycling.[95] For reefs nearer land, additional nutrients are derived naturally from terrestrial sources. An overabundance of nutrients increases plant growth, resulting in effects like algal blooms and increased macroalgal growth, which can affect ecosystem health[96], for example through reducing available light for seafloor communities and trapping sediment.

Most inshore areas of the southern two-thirds of the Region are exposed to elevated nutrient concentrations.

Modelling of pre-European exposure to dissolved inorganic nitrogen from river discharges suggests that it was concentrated very close to the coast around river mouths, with the largest plume adjacent to the Wet Tropics rivers and the Burdekin River.[34] Since European settlement in the adjacent catchment, nutrient loads entering the Region are estimated to have increased[40,97] almost two-fold for both nitrogen and phosphorus.[97] Most inshore areas of the southern two-thirds of the Region are now exposed to nutrients at elevated concentrations[98] (Figure 3.9), disrupting nutrient cycling in the ecosystem.

Recent investments in improving land management practices from 2009 to 2013 have resulted in a modelled 16 per cent reduction in the average annual dissolved inorganic nitrogen load leaving the catchment.[56,99] Long-term benefits are expected to follow for the Region's ecosystem.[98,100]

However, the lag between improved practices and environmental benefits is likely to mean that the nutrient cycle will continue to be affected for some decades.[57]

Offshore and remote northern areas of the Region are believed to be mostly unaffected by increased nutrients and hence nutrient cycling is assumed to be functioning naturally.

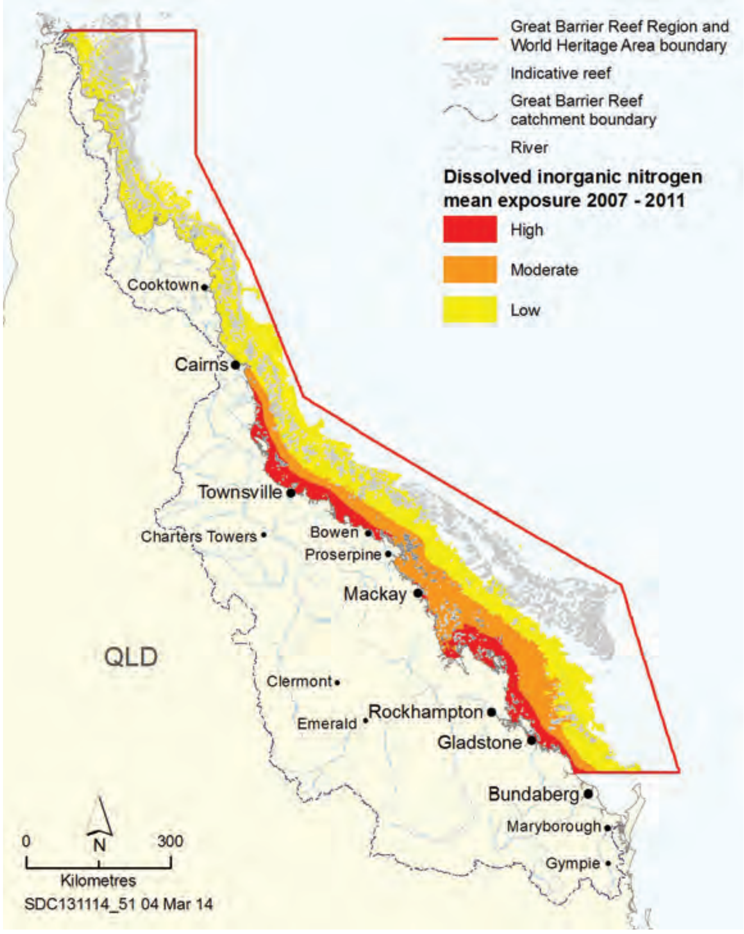


Figure 3.9 Exposure to dissolved inorganic nitrogen, 2007–2011
Nutrients, such as dissolved inorganic nitrogen, are now present in the ecosystem at far higher concentrations than those likely to have been present prior to European settlement. The assessment classes (high, moderate and low) are relative and derived from a combination of scaled river loads data and flood plume frequency analysis from remote sensing data. The mean of the five annual distributions was selected as a way of factoring in inter-annual variability in river discharge, although it is recognised that this period was characterised by several extreme rainfall events.
Source: Brodie et al. 2013[60]

3.3.2 Ocean pH

It is estimated that an increase in the amount of carbon dioxide absorbed by the ocean has already caused a decrease in global ocean acidity of 0.1 pH units compared to the long-term average.[101,102] From a current pH of 8.1[102], it is predicted that the ocean could fall to a pH of about 7.6 by 2100, with slight regional variation.[66]

The pH of the ocean is of vital importance to many marine animals and plants. Decreases in ocean pH can have a range of impacts on species and habitats (see Section 6.3.2) and it is predicted that the ecosystem will be affected on a Reef-wide scale. For example, more acidic water can reduce the ability of some animals to grow strong calcium carbonate shells or skeletons[101,103] (Section 3.4.8). The consequences of decreases in pH and other changes in ocean chemistry are just beginning to be understood.[102]

Decreasing ocean pH is likely to affect the ecosystem Reef-wide in the future.

3.3.3 Ocean salinity

Recent floods have caused periods of reduced salinity in inshore areas and beyond.

The salinity of Great Barrier Reef waters can vary from zero in the surface waters near river mouths to 37 parts per thousand, but overall remains generally stable around an average of 35 parts per thousand.[104] Inflow from the creeks and rivers in the Great Barrier Reef catchment naturally forms a thin layer of

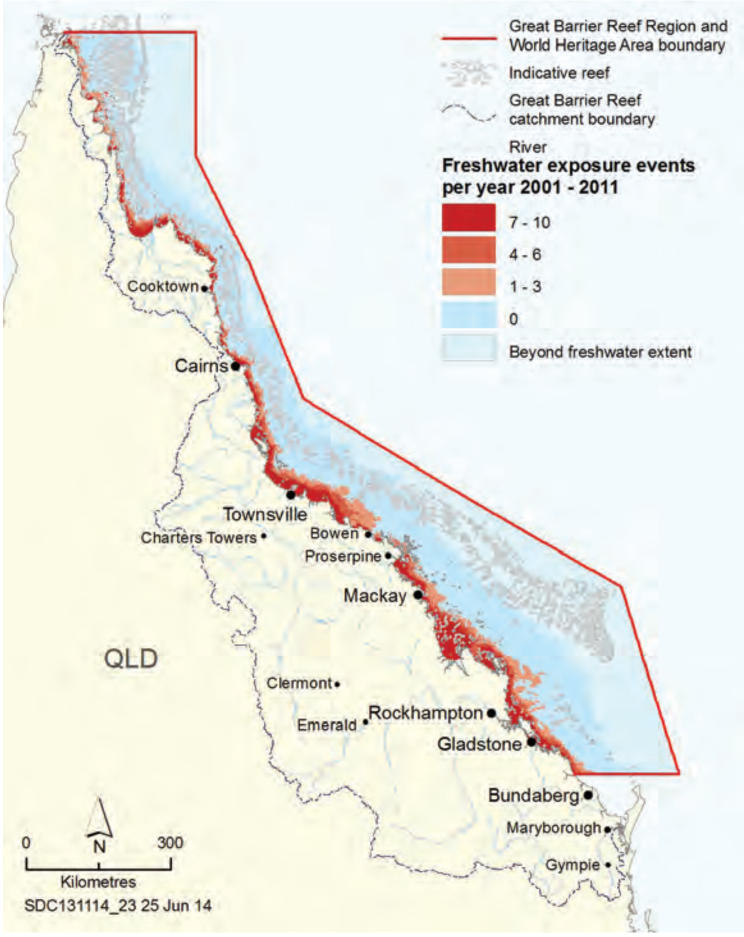


Figure 3.10 Freshwater exposure, 2001–2011
Frequency of freshwater plumes in the Region between 2001 and 2011 modelled from remotely sensed concentrations of dissolved organic matter (a proxy for freshwater). Gradings are based on the number of times a freshwater plume with a measured concentration of salinity less than 30 (+/- 4) parts per thousand was observed in any given year over the 10-year period. Gradings are expressed as: low (1–3 events), medium (4–6 events) and high (7–10 events) where the maximum frequency of events observed was 10. Source: Maynard *et al.* in preparation[109]

freshwater on the surface of the heavier seawater and during floods, this layer may extend to mid-shelf reefs.[44,105,106,107] This can result in extensive fluctuations in ocean salinity, especially in intertidal and shallow habitats. Heavy rainfall directly on the ocean can also reduce surface salinity. Salinity is a key driver of ocean circulation.[4]

Abnormally large freshwater inflows can have negative effects, for example low salinity bleaching and mortality in corals[108]. Much of the inshore area of the Region has experienced freshwater events between 2001 and 2011 (Figure 3.10). Identifying the effects attributable to decreased salinity is confounded by the effects of pollutants carried by the waters, and by other concurrent processes, for example cyclone damage.[92]

3.4 Current condition and trends of ecological processes

3.4.1 Microbial processes

Microbes, including viruses, bacteria and fungi, are estimated to account for more than 90 per cent of the ocean's biomass and live in a wide range of habitats.[110,111] Microbial processes play a central role in supporting and maintaining many other forms of life. These processes regulate the composition of the atmosphere, influence climate, recycle nutrients, and decompose pollutants.[112] Despite their importance, microbial processes are poorly understood[113]. There are some observable changes in bacterial levels in the Region's water column and in benthic organisms, such as the frequency of diseases (Section 3.6.1) and amounts of marine snow — a continuous shower of mostly organic detritus falling from the upper layers of the water column.[114,115,116]

Microbial processes are responsive to changes in environmental conditions.

Microbial processes are very responsive to organic and inorganic nutrient concentrations and changes in environmental conditions such as temperature, pH, salinity and oxygen.[113,117] In recent decades, there has been a global increase in reports of disease in marine species, linked to increasing temperatures and thermal stress.[117]

3.4.2 Particle feeding

Particle feeding, including filter feeding and detritivory, is undertaken by a wide range of animals from the very large (whale sharks and some whales) to the microscopic (copepods). Most marine invertebrates, such as sea cucumbers, scallops, sponges, corals and many crustaceans (for example prawns and some crabs) are particle feeders.[95] They are an important part of the energy and nutrient cycle, feeding on detritus, bacteria, plankton and particulate nutrients.[95] Ecosystems that have become severely degraded through high nutrient levels, anoxia or acidification are almost entirely populated with benthic particle feeders.[118]

The process of particle feeding is likely to have deteriorated.

The clay fraction of sediments can affect particle feeders as their feeding mechanisms are readily choked by these sediments or are kept clean at a high metabolic cost.[114,119,120] Turbidity increases the rate of particle feeding by corals.[121]

Hard coral cover is estimated to have halved in the last 30 years[14], which is likely to have affected levels of particle feeding. Some other particle feeding species have been or continue to be commercially harvested, such as prawns, scallops and some crabs. They range from being considered 'sustainably fished' such as banana prawns; to 'not fully utilised by fisheries' such as endeavour prawns; and 'data deficient' such as burrowing blackfish sea cucumbers.[122] Populations of some sea cucumber species do not appear to have recovered from previous harvesting (see Section 8.3.3).[118,123]

3.4.3 Primary production

Most food webs are based on primary production — the production of food by photosynthesis using energy from the sun. It is closely linked to concentrations of available inorganic nutrients.[124] In tropical marine ecosystems such as the Great Barrier Reef, primary production is undertaken by plants such as macroalgae, turf algae, seagrasses and mangroves, and, in large part, by phytoplankton and symbiotic algae in corals and some other animals (such as giant clams).

Some seafloor primary producers, such as seagrass have declined; others such as macroalgae may be more abundant.

The presence of elevated levels of chlorophyll *a*, together with extensive phytoplankton blooms following the discharge of nutrient-rich flood waters, suggests open water (pelagic) primary production in inshore areas of the southern two-thirds of the Region is significantly affected by elevated nutrient loads.[46,124,125] This in turn affects zooplankton populations, such as larvae of the crown-of-thorns starfish (Section 3.6.2).[125]

Certain primary producers, such as seagrasses, have declined in some areas, resulting in a loss of primary production, especially in central and southern areas.[83,126] However, there is evidence of increased macroalgae at some reefs[127], indicating a possible increase in primary production.

3.4.4 Herbivory

Consuming plants for food (herbivory) is a key process for the health and resilience of tropical marine ecosystems, including coral reefs[96,128,129]. Herbivores have a particularly important role in maintaining reef ecosystems — without their constant presence, many reefs would be rapidly overtaken by algae that compete with corals for space to establish and grow.[96,128]

Fish are important herbivores in the coral reef habitats of the Great Barrier Reef.[129] Studies on the Great Barrier Reef suggest that populations and diversity of herbivorous fishes continue to be sufficient to control algal growth on most offshore reefs[128,130], in part because there is minimal direct pressure on their populations.

Declines in dugongs are likely to have affected herbivory in the Region.

Dugongs and green turtles are important herbivores in seagrass meadow habitats.[131,132,133,134] Dugongs forage mainly on seagrass, and green turtles on seagrass and macroalgae. The dugong population has declined significantly in the southern two-thirds of the Region[135] but remains stable for the area north of Cooktown (see Section 2.4.17). Populations of green turtle in the Region are still affected by legacy impacts of commercial harvesting (see Figure 2.1). The southern population is now increasing while the northern population is showing early signs of decline after previous significant increases (see Section 2.4.11). Population changes affect levels of herbivory in the Region which can in turn affect seagrass community structure and productivity.[136]

Levels of herbivory are likely to have been affected by recent broadscale losses in seagrass abundance (see Section 2.3.4).[33]

3.4.5 Predation

Predation (animals consuming other animals) has a fundamental influence on marine ecosystems by controlling the abundance of many prey animals and through a range of cascading effects through the food web.[137] Predators in coral reef ecosystems include most big bony fishes and sharks, as well as a wide array of smaller fishes and invertebrates, seabirds, some marine turtles, sea snakes, crocodiles and some marine mammals.[138]

While little is known about trends in the ecological process of predation in the Region, the condition of predator populations can provide an indication of levels of predation and the condition of the supporting food web. The Outlook Report 2009 reported on research indicating that at some locations on the Great Barrier Reef there has been a marked decrease in populations of coral trout and some reef shark species both of which are targeted by fishing activities.[139] Over the last five years none of the predator species monitored have shown strong recovery and many remain at reduced numbers or their population sizes are poorly understood.

Decreased predator populations affect the process of predation.

Predation has a fundamental influence on the ecosystem
© Matt Curnock

Examples of effects on predator populations include:

- Coral trout numbers continue to occur in lower densities on reefs open to fishing compared to similar reefs closed to fishing (see Section 2.4.8).[140]
- Of the four highest ecological risk predatory fishes taken in the East Coast Inshore Fin Fish Fishery[141], two (king threadfin and barred javelin) have an undefined stock status and the other two (black jewfish and giant queenfish) were not assessed in the 2012 Queensland stock assessment.[122]
- The Queensland shark control program has targeted predators such as tiger sharks since its inception in 1962.
- Many sharks are incidentally caught in commercial fisheries.[138,142]
- There are declining populations of some seabird populations (see Section 2.4.13) and suspected declines in some dolphin species (see Section 2.4.16).

The partial recovery of crocodile and loggerhead turtle populations will have increased predation by those species.

3.4.6 Symbiosis

Symbiosis is the interdependence of different organisms that benefits one or both participants. There are a wide range of symbiotic relationships in the Great Barrier Reef including those that are mutually beneficial (mutualism); beneficial for one organism without affecting the other (commensalism); and beneficial for one organism to the detriment of another (parasitism).

Symbiotic relationships are likely to have deteriorated in the southern two-thirds of the Region.

One of the most important symbioses in the Region is between corals and microscopic algae.[143] This symbiosis is an example of mutualism. The algae photosynthesise like other green plants, however up to 95 per cent of the nutrients produced are used by the coral host organism.[143,144] In return the coral provides the algae with a safe habitat. An example of commensalism is the association between the Chelonibia barnacle and its marine turtle hosts.[145] Isopod crustaceans gaining shelter and food by living on the gills of many reef fishes is an example of parasitism.[146] High numbers of parasites can be an indicator of poor environmental conditions.[147]

Very little is known about the condition and trend of most symbiotic relationships in the Region. Based on the overall condition of the ecosystem, it is likely they are in good condition in the northern third of the Region. The poorer overall condition of the ecosystem in the southern two-thirds of the Region[148] may have affected symbiotic processes. The extent of the effect would depend on the individual species involved. In particular, the coral–algal symbiosis will have been significantly affected by the decline in hard coral cover (see Section 2.3.5) and thermal stress events (resulting in coral bleaching) (Section 3.2.6).[149,150,151,152,153]

3.4.7 Recruitment

While not included in the Outlook Report 2009, recruitment is an important ecological process that contributes to the replenishment of populations and to processes such as productivity, reef building and habitat connectivity.[154] The sustainability of a population relies on sufficient individuals being recruited through their life history stages and into the adult population. The global significance of some of the Reef's recruitment processes, including coral spawning, marine turtle and seabird nesting, and humpback whale calving is recognised as a key attribute of its outstanding universal value.

Although poorly understood, recruitment processes for many species are likely to be functioning well across most of the Region. However, there are some species and groups of species which are known to be affected by poor recruitment.

Recruitment is reduced for many key species.

For coral reefs, a key habitat of the Region, the apparent lack of recovery of many severely degraded reefs in the inshore southern two-thirds of the Region is partly due to poor coral larval recruitment and low juvenile survival.[155] Between 2010 and 2011, there was a 43 per cent decline in recruitment of inshore corals.[89] This continued from a general decrease since 2007, although there were a few isolated recruitment pulses.[89] Surveys of the 2011 recruitment season recorded the lowest number of settled corals since the surveys began in 2005.[89] As coral larvae need hard surfaces to settle on, increases in macroalgae (see Section 2.4.3) are likely to have affected coral recruitment in some areas.[156] Increased sedimentation (Section 3.2.4) inhibits the settlement of coral and smothers newly settled recruits.[85,156,157]
Predicted changes in ocean pH are likely to affect the settlement rates of coral larvae and the crustose coralline algae that provide important settlement substrate.[158]

Fishing in spawning aggregations affects recruitment of the aggregating species, with potentially long-term effects.[159] Given the longevity and late sexual maturity of many aggregating fish species, the effects of fishing in spawning aggregations may not be evident for many years — increasing the risk of overexploitation.[159] There is limited information about the status of spawning aggregations in the Region. However, declines in some fish species (see Section 2.4.8) and the changes in fish abundance between zones open and closed to fishing[139,160,161,162] indicates that recruitment is likely to have been affected in areas open to fishing.

Broadscale losses of seagrass meadows are likely to have affected both the recruitment of seagrass, and a range of other species that rely on the habitat as nursery grounds[163,164] or for food — for example the availability of seagrass is a key factor in the reproductive rate and successful recruitment of dugongs and green turtles (see Chapter 2).[165] For slow-breeding species that are in low abundance, such as dugongs[166,167], recruitment of juveniles into the adult population is a key part of their recovery.

For green and loggerhead turtles there is reduced recruitment of juveniles into the foraging stock[168] and reduced recruitment rates of first-time nesting females into the nesting stock.[169,170]

Deteriorating recruitment has been evident in some seabird populations. Some years have seen almost complete reproductive failure of the wedge-tailed shearwaters in the Capricorn–Bunker group of islands. This is likely due to a decreased growth rate of chicks as a result of a reduced ability for adults to supply food, linked to higher than normal sea surface temperatures.[171] This directly affects the level of recruitment of juveniles into the adult population.

3.4.8 Reef building

Only a small proportion of a coral reef is living coral — the remainder is coral-based pavement, boulders, fragments, beach-rock accretions and sediment.[172] Reef building is the net result of processes that form calcium carbonate (calcification) and the physical, chemical or biological erosion that removes it. The formation of calcium carbonate skeletons by living coral is the primary source of calcification, however corals are only one of a number of groups that contribute to reef construction.[172] Others include molluscs, crustaceans, foraminifera and red and green algae.[172] Many of the organisms that calcify at high rates benefit from photosynthesis by symbiotic algae (Section 3.4.6).[173] The rate of deposition of calcium carbonate is dependent on light (Section 3.2.7), temperature (Section 3.2.6) and the availability of carbonate ions in the water column.[174]

Declines in coral cover are likely to have affected the contribution of coral to the reef building process.

Increasing sea temperature and ocean acidification are likely to be contributing to reduced calcification rates of corals throughout the Region.[101,175] Skeletal records of massive corals from the inshore Great Barrier Reef indicate that between 1990 and 2005 there was an 11 per cent decline in calcification.[101,176] This is the fastest and most severe decline in at least 400 years.[101] There is no information on more recent trends.

The impact of future changes in temperature and ocean acidification on the process of calcification is uncertain. Decreasing ocean pH has an increasing negative effect on the calcification process and thus progressively slows the process of reef building.[101,174,177] However, the impact varies between coral species as well as between organisms.[178] The predicted concurrent warming of the oceans speeds up the calcification process — potentially counteracting to some extent the negative effects of decreasing ocean pH at some reefs.[179] In addition, ocean chemistry fluctuates greatly at small scales across a reef, and corals are capable of modifying their seawater carbon chemistry, thus potentially negating some of the possible large-scale impacts of climate change on this reef building.[180]

The contribution of coral to the reef building process is likely to be higher in the northern areas of the Region as coral cover remains relatively high[14]. The reduced amount of living coral[14] in the southern two-thirds of the Region[14] is likely to have affected its contribution to reef building processes.

3.4.9 Competition

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

There is little information about the multitude of competitive interactions.

The most studied competition that occurs on coral reefs is that between coral and macroalgae.[181,182,183] For coral reefs to be maintained in the ecosystem there must be continual settlement and growth of juvenile corals.[181] This recruitment may be hampered if a reef becomes overgrown by algae.[184] On degraded coral reefs in nutrient-rich waters, it is likely that a phase shift will occur from a coral-dominated reef to one dominated by macroalgae; this phenomena has been reported from some reefs in the Region.[127] Decreasing ocean pH is predicted to further change the balance of this competition in favour of the algae, possibly as a result of changes in corals' chemical competitive mechanisms.[185,186]

The multitude of other competitive interactions in the Great Barrier Reef ecosystem forms a complex network; relatively few have been studied and little is known of their condition.

3.4.10 Connectivity

Ecological connectivity is the movement of species and materials across and through landscapes and seascapes. It includes processes as different as nutrient flows, migration, larval dispersal and gene flow and is important to every aspect of the Reef ecosystem.

Marine species and habitats remain connected; connectivity with some terrestrial habitats is disrupted.

Within the Region there are connections between estuarine and inshore habitats and those further offshore; north–south connections between habitats and connections between open water and seabed habitats. There are also larger scale connections to environments outside the Region, for example the Torres Strait, Coral Sea and Antarctica. Connectivity may be related to migration between breeding and foraging areas (for example humpback whales, seabirds, and marine turtles), movement by ocean currents (for example coral spawn, fish larvae and marine turtle hatchlings) or dispersal (for example dugongs and fishes). Genetic connectivity is a crucial process in the Region's ecosystem. Currents can play a major role in genetic connectivity for some marine animals. For example, changes to major ocean currents and other hydrodynamic features could have important effects on the dispersal and survival of tropical fish larvae.[187,188] Genetic connectivity between some reefal areas remains strong with evidence of the larvae of two coral reef fish species transferring from areas in the Keppel Islands that have been closed to fishing to adjacent areas open to fishing.[160]

Having functional connections between the Great Barrier Reef and adjacent land areas is very important to the Reef ecosystem, allowing water, nutrients and sediments to be transported and providing a movement corridor between feeding and breeding areas for some marine species.[189] For example, as many as 78 Great Barrier Reef marine and estuarine fish species use freshwater systems for part of their life cycle.[190] Aquatic connections between freshwater and marine environments are still functioning largely undisturbed in the Cape York area.[25,189] In contrast, connecting waterbodies have been substantially altered in the central and southern catchment[25,191,192,193], mainly due to changes to hydrological flows and the construction of bunds, dams, weirs and other structures.[189,192,193,194,195] For example, 41 impediments to natural environmental flows have been identified as affecting the internationally listed Bowling Green Bay wetland[193], and in the wider Burdekin region there are estimated to be more than 1000 obstructions to fish passage.[192]

Aquatic connectivity is also provided through groundwater which can enter the Region via wonky holes — submarine groundwater discharge points (Section 3.2.3).[30]

Connectivity between habitats can increase the resilience of the Reef ecosystem. For example, connectivity between mangroves and coral reefs provides benefits for herbivorous fish populations, which contribute to coral reef resilience by grazing on algae.[196] However, connectivity across seascapes can also spread macroalgae, disease, and invasive species that have the potential to affect ecosystem health.[197]

Migration is a key component of connectivity on a broad scale. Whale migration is recognised as one of the superlative natural phenomena that contributes to the Reef's outstanding universal value. A number of species of conservation concern live in the Reef for only part of the year or for part of their life — this includes humpback[198] and dwarf minke whales[199]; green, loggerhead and hawksbill turtles[200,201,202]; and some seabirds[203] and shorebirds. There is emerging evidence that some seabirds that nest in the Region over-winter far beyond it, for example some non-breeding wedge-tailed shearwaters have been tracked migrating from Heron Island to Micronesia.[204] Some fish species, like marlin, are also highly mobile and travel well beyond the Region for parts of their life cycle.[205]

Threats to migratory species often occur well beyond the Region. For example, some marine turtles that nest or forage in the Region may be injured or killed, or ingest marine debris, in areas hundreds or even thousands of kilometres away.[170,206] Similarly, migratory shorebirds may be affected by factors during other parts of their annual journey to the northern hemisphere.[207]

3.5 Current condition and trends in terrestrial habitats that support the Great Barrier Reef

The Outlook Report 2009 highlighted the loss of coastal habitats as a high risk to the long-term outlook of the Region's ecosystem. Based on the outcomes of extensive, synthesised research since then[189,208,209,210,211,212,213,214,215], supporting terrestrial habitats in the catchment have been added to the assessment of ecosystem health. The habitats are grouped into seven categories: saltmarshes; freshwater wetlands; forested floodplains; heath and shrublands; grasslands and sedgelands; woodlands and forests; and rainforests.

These habitats play a key role in supporting the Reef ecosystem, particularly by providing ecosystem services such as slowing overland water flow, trapping sediments and nutrients, and providing feeding and breeding areas for marine species. Aquatic connections directly and indirectly link land-based habitats

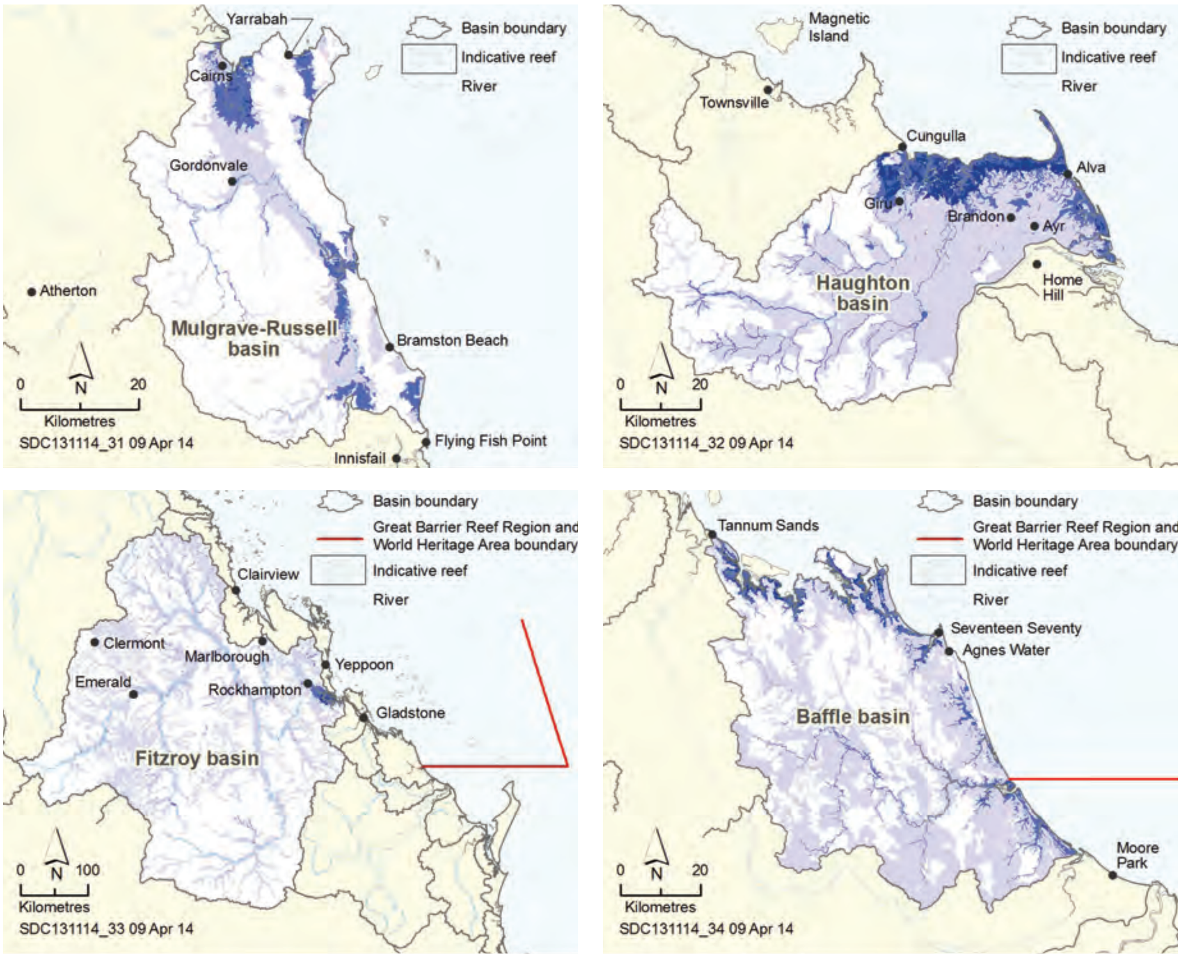


Figure 3.11 Examples of areas in catchment basins that support the Great Barrier Reef
Examples of areas of the Mulgrave-Russell, Haughton, Fitzroy and Baffle basins that support the Region. The darker areas shown are of higher importance to the healthy functioning of the Great Barrier Reef ecosystem because of their proximity to and connectivity with the Great Barrier Reef. The analysis takes into account wetlands and areas that are frequently inundated or flooded, as well as areas influenced by tidal processes and storm surges. It represents the surface level hydrology only and does not include groundwater. Source: Great Barrier Reef Marine Park Authority 2014[216]

to the marine system (Section 3.4.10). Figure 3.11 presents preliminary maps of the relative importance of areas within four basins of the Great Barrier Reef catchment to the healthy functioning of the marine ecosystem. They illustrate the particular importance of tidal and riparian habitats to the Region.

Past broadscale land clearing, principally in the southern two-thirds of the Great Barrier Reef catchment, has significantly affected each of the supporting terrestrial habitats. Clearing began in the 1870s and was undertaken to allow more intensive agricultural use. It further increased when intensive cropping on the coastal floodplain began in the early 1900s and again in the 1930s and 1940s when heavy machinery made clearing easier. The rate of clearing continued to increase until the late 1990s.[189] Ongoing agricultural use of these habitats also affects their ability to support the Reef ecosystem.

Past broadscale land clearing has affected habitats that support the Reef.

The majority of vegetation in the catchment now is classed as 'non-remnant', that is it has been modified to the extent that its natural ecological function has been modified or lost. This classification includes areas of regrowth from past clearing, some of which continues to provide functions that support the Region[189]. Changes in the extent of each habitat within the Great Barrier Reef catchment are summarised in Table 3.1 and mapped in Figure 3.12.

The resultant loss and modification of habitats has led to significant increases in pollutants, principally nutrients and sediments, entering the Great Barrier Reef lagoon[189] which has reduced the ecosystem's ability to bounce back after impacts, especially in southern inshore areas.[217] In addition, the loss of freshwater coastal habitats has affected some ecological functions and numerous marine species, including the freshwater sawfish which is now threatened, in part, due to habitat loss.[218]

Table 3.1 Changes in the extent of supporting terrestrial habitats
Source: Great Barrier Reef Marine Park Authority, 2012[189] with minor updates

Supporting terrestrial habitat	Total area before European settlement (km²)	Total area remaining (km²)	Proportion remaining
Saltmarshes	2146	1830	85 per cent
Freshwater wetlands	1431	1237	86 per cent
Forested floodplain	24,597	12,655	51 per cent
Heath and shrublands	5351	5025	94 per cent
Grass and sedgelands	12,364	5988	48 per cent
Woodlands	105,123	64,592	61 per cent
Forests	239,602	145,379	61 per cent
Rainforests	26,886	16,744	62 per cent

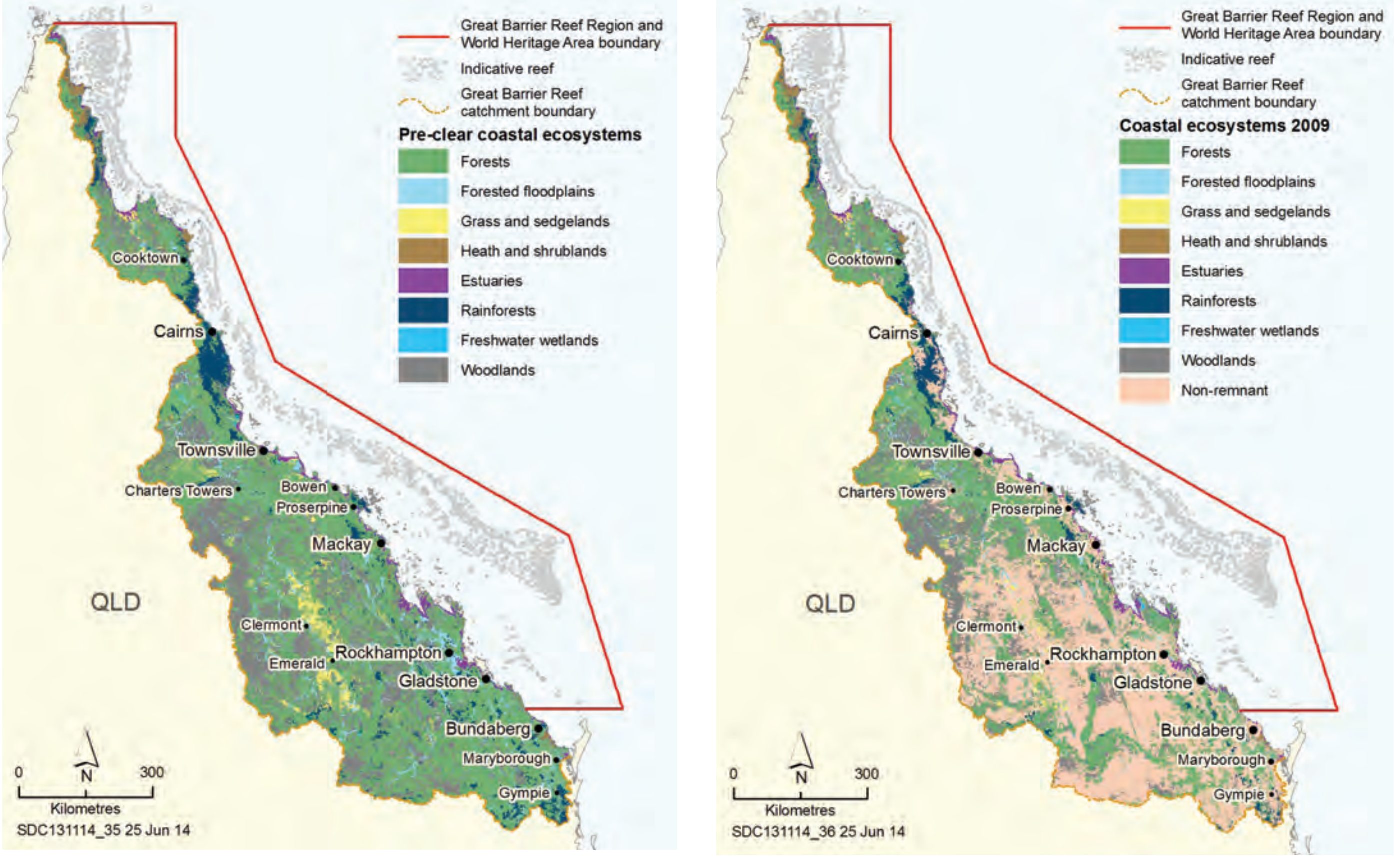


Figure 3.12 Changes in supporting terrestrial ecosystems, pre-European and 2009
Before European settlement there were extensive areas of forests, woodlands and forested floodplain interspersed with wetlands and other aquatic habitats across much of the catchment. These habitats supported the Great Barrier Reef ecosystem. An extensive area of the catchment has been changed from forest to grassland for grazing purposes and there has been a significant increase in non-remnant vegetation. Source: Great Barrier Reef Marine Park Authority, 2012[189]

3.5.1 Saltmarshes

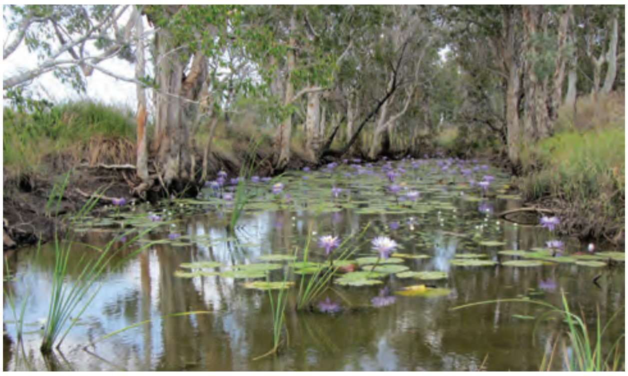
Some saltmarsh areas have been modified.

Saltmarshes are an important, highly productive, interface between marine and terrestrial environments in the upper intertidal area along the length of the Great Barrier Reef coast.[219,220] They provide feeding and breeding areas for many marine species including many commercial fish and prawn species.[163,221] Coastal development has modified saltmarshes, affecting more than 15 per cent of the habitat in the catchment.[222] The impact is highest in areas with grazing and cropping, urban growth or large population centres.[189]

3.5.2 Freshwater wetlands

Freshwater wetlands remain intact in many areas; many are functioning poorly.

Freshwater wetlands slow the overland flow of water and capture and recycle nutrients and sediments that would otherwise enter the Great Barrier Reef.[189] They are also used by some marine species for parts of their life cycle and are important dry season refuges for many species including the threatened largetooth sawfish.[223] Freshwater wetlands at a whole-of-catchment scale are relatively intact, but many are functioning poorly due to a range of factors, including loss of connectivity, sediment and nutrient overload, changes to groundwater and weed infestations.[189] In areas where ecological function of freshwater wetlands is good, water quality and coastal habitats tend to be in better condition than where it is lost or modified.[214] As the accuracy of mapping of wetlands improves, estimates of their extent and loss are refined, especially for infrequently inundated wetlands on highly developed coastal floodplains. In some coastal floodplain basins (for example the Barron, Kolan and Johnstone rivers) up to 80 per cent of freshwater wetlands have been lost.[189] The rate of wetland loss has slowed in recent years.[189]


Freshwater wetlands capture and recycle nutrients

3.5.3 Forested floodplains

Forested floodplains help slow, capture and recycle nutrients and sediments and are important nursery areas for many species with connections to the Great Barrier Reef.[189] Forested floodplains also protect the soil surface from the erosive forces of rain.[189] Since European settlement, the area of forested floodplain has been reduced by nearly 50 per cent across the catchment.[189] The largest loss is in the Fitzroy basin which is estimated to have lost 6638 square kilometres of forested floodplains. Much of its remaining 12,700 square kilometres extent is grazed.[189] The habitat has been affected by clearing and land modification, changes to overland and groundwater flows, weed and pest invasion, water extraction and reduced connectivity.[189]

The area of forested floodplain has been halved and much of it is grazed.

3.5.4 Heath and shrublands

Heath and shrublands help slow the overland flow of water; prevent erosion; recycle nutrients and sediments; and are important as buffers on steep coastal hill slopes.[189] Approximately 94 per cent of the heath and shrublands in the catchment remains intact, with about 78 per cent protected in national parks, conservation areas and state forests.[189] Almost 70 per cent of the current total area of heath and shrublands occurs in the Cape York region.[189]

3.5.5 Grass and sedgelands

Grass and sedgeland habitats occur throughout the catchment. They are typically composed of perennial native grasses with no canopy of trees. The habitat is used for feeding and roosting by migratory birds; helps slow the overland flow of water; and captures nutrients and sediments.[189] Little modification has occurred in the Cape York region.[189] The greatest loss has been in the Burdekin and Fitzroy regions where more than 40 and 60 per cent, respectively, of the habitat has been lost. Coastal grasslands have been extensively modified for agricultural production or urban settlements, particularly in the Burdekin and Fitzroy regions.[189]

Grasslands and sedgelands have been modified extensively in southern catchments, especially close to the coast.

3.5.6 Woodlands and forests

Woodlands and forests regulate sediment and nutrient supply to the Great Barrier Reef and reduce flooding by slowing the overland flow of water.[189] They also indirectly influence the ecosystem through their contributions to the hydrological cycle, for example evapotranspiration, cloud formation and rainfall generation.[189]

The extent of woodlands and forests varies throughout the catchment. There have been significant losses of woodland habitats in the Burdekin and Fitzroy regions and an average loss of 39 per cent throughout the catchment.[189] It is estimated that the total loss of forests and woodlands since European settlement is 134,754 square kilometres.[189] Forests in the Cape York and the Wet Tropics regions have remained largely intact. The loss of woody vegetation is thought to be due mainly to clearing for agriculture and, to a much lesser extent, urban development.[189]

3.5.7 Rainforests

Rainforests minimise soil loss from erosion, including binding and stabilising soils, and provide foraging habitat for species that also use Great Barrier Reef islands, such as pied imperial pigeons. There have been losses in rainforest habitats throughout the catchment, in particular the Wet Tropics, Fitzroy and Burnett Mary regions.[189] The loss of rainforest has averaged 38 per cent across the Great Barrier Reef catchment since pre-European settlement.[189] Logging of rainforests in north Queensland ceased 26 years ago. The Wet Tropics rainforest is now inscribed on the World Heritage List and the habitat is well protected.

The greatest losses of rainforest have been in the Wet Tropics, Fitzroy and Burnett Mary regions.

3.6 Current condition and trends of outbreaks of disease, introduced species and pest species

3.6.1 Outbreaks of disease

Whether natural or introduced, disease outbreaks are an indicator of stress in an ecosystem, species or habitat[224]. They have affected a range of the Region's species in recent years, including corals[92], green turtles[225,226], dugongs[226] and the Queensland groper[227].

Coral disease has been identified as a key indicator of coral reef resilience due to its prevalence in disturbed areas[228] such as those exposed to flood events[116], higher levels of turbidity and sedimentation[229], and high sea temperatures[230,231]. In other countries, degraded coral reef ecosystems are likely to have a high incidence of diseases.[232]

Disease has affected corals, green turtles, dugong and the Queensland groper in recent years.

Coral disease is being increasingly observed on the Great Barrier Reef and is predicted to increase in the future.[233,234] Major outbreaks of the naturally occurring white syndrome disease have been recorded after especially warm years on reefs with high coral cover, indicating a potential link between coral disease and increasing sea temperatures as a result of climate change.[230,233,235,236] More recently, coral disease has also been linked to cooler-than-normal conditions.[230]

White syndrome disease on coral

Fibropapilloma lesions around the tail of a young green turtle
© James Cook University, photograph by Ellen Ariel

Reduced salinity can play a role in coral disease. For example, between January and March 2009, following a period of moderately high sea surface temperature and a severe decline in salinity (to 20 parts per thousand), there was a 10-fold increase in the average number of coral colonies infected with disease in Geoffrey Bay, Magnetic Island.[231] When salinity returned to normal (about 35 parts per thousand), the average number of diseased colonies declined rapidly.[231]

Investigations into a suspected outbreak of disease in fishes in Gladstone Harbour concluded that the majority of lesions in barramundi were the result of physical damage after being washed over the Awoonga Dam during heavy rainfall. The stress of their forced relocation and increased crowding and competition for food resulted in the fish becoming more susceptible to parasites and disease.[237]

Outbreaks of disease have also been observed in species of conservation concern. Green turtle fibropapillomatosis was first reported in Australia more than 40 years ago[238] and the frequency of recorded cases increased up to the early 1990s[239]. In the Queensland population, fibropapillomas are rare on green turtles from offshore reefal environments, but prevalent in semi-enclosed bays.[170] There is evidence from other parts of the world of a link to land-based run-off.[240] The overall effect on the Region's population from this disease currently appears to be low[241], and there are instances of the species recovering naturally[170,242].

Necropsies conducted on deceased dugongs indicate disease was the cause of death for between 20 and 25 per cent of the 298 animals examined between 1996 and 2010 for which the cause of death was determined.[243] In 2011, after extreme weather, 30 dugongs were recorded as dying of disease or ill health in Queensland.[226] Of these, 12 died after extended ill health and had poor body condition, pneumonia was associated with the deaths of three dugongs, and a further 15 died of unidentified disease.

Disease may be a factor in causing inshore dolphins to strand, as was the case in 2000 and 2001[244], but there has been little recent disease monitoring of dolphins within the Region.

Investigations into the deaths of 94 Queensland gropers between 2007 and 2011 confirmed that 12 had died from *Streptococcus agalactiae* infection.[227]

There is limited information about disease in species that are not iconic or targeted during fishing activities.

3.6.2 Outbreaks of crown-of-thorns starfish

Crown-of-thorns starfish are a major predator of coral. An adult crown-of-thorns starfish can consume up to 478 square centimetres (about the size of a dinner plate) of coral each day.[245]

Under natural conditions, it is thought that crown-of thorns starfish populations increase to outbreak concentrations in a 50 to 80 year cycle.[246] However, human impacts may have increased the frequency and severity of outbreaks.[246] Over the past half-century, they have occurred from 1962 to 1976, 1978 to 1990, and 1993 to 2005[247] and there is currently another outbreak concentrated between Lizard Island and Cairns. An outbreak of crown-of-thorns starfish is considered to be occurring when they are at densities greater than about 30 starfish per hectare.[248,249]

Outbreaks of crown-of-thorns starfish are one of the major causes of coral cover decline in the Region[14] (see Section 2.3.5). Each outbreak has resulted in severe reductions in coral cover on a regional scale, particularly in the central area of the Region.[14] Outbreaks appear to initiate in the area between Lizard Island and Cairns, and gradually progress south over several years,[250] although independent outbreaks have been observed in the Swain Reefs in the far south (Figure 3.13).

There are indications that increased nutrient loads contribute to crown-of-thorns starfish outbreaks due to increased food supply and therefore survival of their larvae (Figure 3.14).[246,252,253]

Importantly, the increased frequency of outbreaks, combined with other stresses on corals[14], means coral populations are increasingly unable to fully recover before the next outbreak occurs.

3.6.3 Introduced species

Introduced species are non-native plants or animals that have arrived in an environment outside their normal distribution. They can have severe negative consequences for local native species and habitats. In the marine environment they are normally transported attached to the hulls of ships, in ballast water, via visits to islands or occasionally through aquaculture operations. Introduced species have been found in both the Region's marine and island ecosystems.

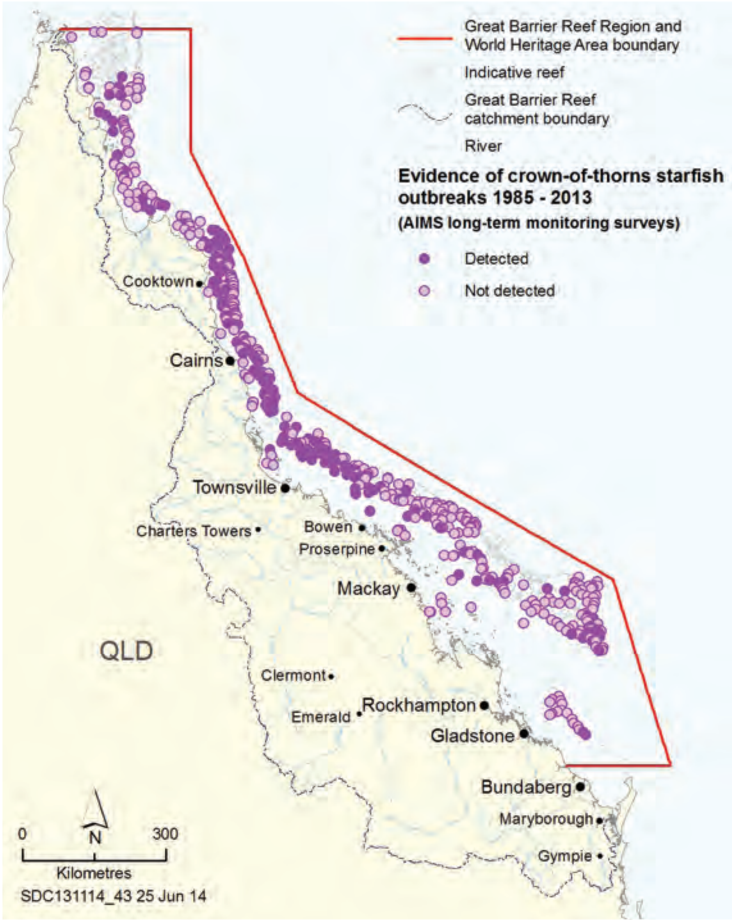
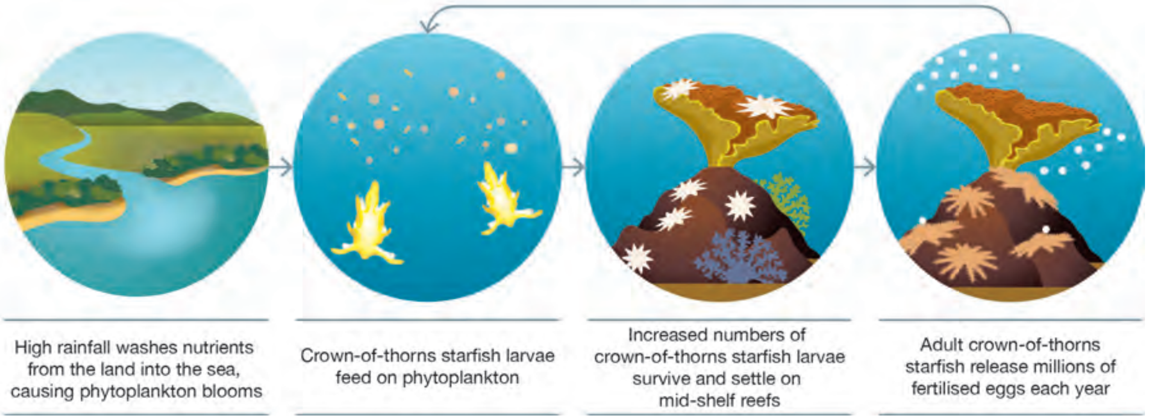


Figure 3.13 Evidence of crown-of-thorns starfish outbreaks, 1985–2013

The map shows areas where evidence of a crown-of-thorns outbreak has been detected as part of the Australian Institute of Marine Science Long-term Monitoring Program. Reefs with an outbreak detected have shown evidence of an active outbreak, an incipient outbreak or recovery from an outbreak. 'Not detected' refers to surveyed reefs with no signs of a crown-of-thorns outbreak within the survey period. Source: Australian Institute of Marine Science Long-term Monitoring Program, unpublished data.[251]



Changes in ecosystem conditions may have resulted in more frequent outbreaks of crown-of-thorns starfish.

Figure 3.14 Potential role of nutrients in the population dynamics of crown-of-thorns starfish

Crown-of-thorns starfish are a major cause of loss of coral cover. One line of evidence suggests that their populations are significantly affected by the concentration of nutrients and, therefore, the amount of phytoplankton in Great Barrier Reef waters. Source: Fabricius *et al.* 2010[246], Brodie *et al.* 2005[247], Furnas *et al.* 2013[254]

Around Australia, approximately 250 introduced marine species have been reported, some of which have had major ecological impacts.[255] For the most part, tropical marine environments seem less susceptible to invasion than temperate ones.[256]

Asian green mussels are considered the highest risk for invasion and impact in Australia.[255] They have been detected in ports along the Great Barrier Reef coastline a number of times over the past decade.[257] The most recent report was in September 2013, when they were found in the internal heat exchanger of a work boat in Mackay port.[257] Extensive investigations in port areas around Mackay did not detect any further mussel introductions.

Introduced species continue to be recorded in and adjacent to the Region.

Introduced species such as rats and dogs affect seabird and turtle nesting on islands and along the mainland coast. Insect invasions have caused serious declines in *Pisonia* forests[258] which are important nesting habitats for several seabird species. In January 2014, an outbreak of fire ants was detected on Curtis Island.[259] Originating from South America, fire ants are very aggressive and voracious feeders on small animals including insects, spiders, lizards, frogs, birds and mammals. They can displace or eliminate some of Australia's unique native species.[260] A fire ant restricted area was declared on Curtis Island and the adjacent mainland following the outbreak, restricting the movement of some earth materials which could contain the introduced species.[261] Introduced weeds have also affected the native vegetation on a number of islands within the Region.[262] There is no regular monitoring of pests on Great Barrier Reef islands.

3.6.4 Other outbreaks

An outbreak of a species refers to a rapid increase in abundance, biomass or population of naturally occurring marine plants and animals. Outbreaks of the naturally occurring crown-of-thorns starfish are examined previously (Section 3.6.2). Outbreaks and blooms of other species can also be harmful or lethal to other marine species as they can compete for resources such as food, sunlight and oxygen.

Extensive phytoplankton blooms can result from nutrients in flood discharges.[125,263]

Outbreaks of some other species are likely to have resulted from declining ecosystem conditions.

Trichodesmium is a cyanobacteria found in nutrient-poor tropical waters. Outbreaks of the species appear as slicks on the water's surface and can be distinctly pungent. It was first described by Captain Cook and, though it occurs naturally, blooms in the central Great Barrier Reef are thought to have increased, possibly due to nutrients in land-based run-off, in particular phosphorus, iron and organic material.[264,265] The blooms have been implicated in directly smothering corals and increasing the bioavailability of heavy metals.[266]

Drupella are marine snails that occur naturally in the Indo-Pacific region, including the Great Barrier Reef, and are known to damage corals when in high densities.[267] Outbreaks have been reported in Western Australia, Japan and the northern Red Sea.[268] To date, no outbreaks of *Drupella* have been reported in the Region, although some tourism operators are permitted to implement control measures for this species. Numbers are monitored regularly at some locations in the Region through the Eye on the Reef monitoring program.

Periodic blooms of the cyanobacterium *Lyngbya majuscula* have been recorded on the Great Barrier Reef.[269,270] *Lyngbya* can smother seagrass, corals and other benthic habitats and has been linked with reduced reproductive success in some turtles in Moreton Bay.[271]

Macroalgal blooms can occur on degraded coral reefs in nutrient-rich waters resulting in a phase shift from a coral-dominated reef to one dominated by macroalgae; this phenomena has been reported from some reefs in the Region.[127]

There is no regular monitoring of outbreaks for any species other than crown-of-thorns starfish and *Drupella*.

3.7 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 five assessment criteria:

- physical processes
- chemical processes
- ecological processes
- terrestrial habitats that support the Great Barrier Reef
- outbreaks of disease, introduced species and pest species.

3.7.1 Physical processes

Outlook Report 2009: Assessment summary
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.

2009 Grade	Current summary and assessment components	Assessment grade and trend				Confidence	
		Very good	Good	Poor	Very poor	Grade	Trend
🟦	**Physical processes:** The condition of all physical processes has declined since 2009. Further changes in processes such as sea temperature, sea level, cyclones and wind, freshwater inflow, waves and currents are expected under climate change projections. Reduced sediment loads entering the Region are likely to improve the processes of sedimentation and light availability in the longer term.		🟦 ↓				
■	**Currents:** There is evidence of intensified flow and accelerated warming in the East Australian Current.	■ ↓				○	○
🟦	**Cyclones and wind:** Between 2005 and 2013, there were six category 3 or above cyclones in the Region. There is emerging evidence of increases in wind strength Australia-wide.		🟦 ↓			◐	◐
🟦	**Freshwater inflow:** Large volumes of freshwater have entered the Region in the past five years, including record flows for some rivers.		🟦 ↓			●	●
🟩	**Sedimentation:** Sediment loads entering the Region continue to be at least double those occurring before European settlement. Improved land management is beginning to reduce sediment input, but measurable improvements in the Region may take decades.			🟩 ↓		●	●
🟦	**Sea level:** The fastest rates of sea level rise in Australian waters are in northern areas. Average sea level rise in the Region is 3.1 millimetres per year.		🟦 ↓			●	●
🟩	**Sea temperature:** The ocean has warmed substantially over the last century. Most of the warmest years have been in the past two decades.			🟩 ↓		●	●
🟦	**Light:** It is likely that light availability has decreased substantially in the inshore areas of the southern two-thirds of the Region due to land-based run-off and extreme weather.		🟦 ↓			◐	◐

Grading statements

■ **Very good** There are no significant changes in processes as a result of human activities.	🟦 **Good** There are some significant changes in processes as a result of human activities in some areas, but these are not to the extent that they are significantly affecting ecosystem functions.	🟩 **Poor** There are substantial changes in processes as a result of human activities, and these are significantly affecting ecosystem functions in some areas.	▩ **Very poor** There are substantial changes in processes across a wide area as a result of human activities, and ecosystem functions are seriously affected in much of the area.

Trend since 2009

↑ Improved
↔ Stable
↓ Deteriorated
– No consistent trend

Confidence

● Adequate high-quality evidence and high level of consensus
◐ Limited evidence or limited consensus
○ Inferred, very limited evidence

3.7.2 Chemical processes

Outlook Report 2009: Assessment summary
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.

2009 Grade	Current summary and assessment components	Assessment grade and trend				Confidence	
		Very good	Good	Poor	Very poor	Grade	Trend
🟩	**Chemical processes:** Nutrient cycling in the Region continues to be affected by nutrients from land-based run-off but changes in land management are likely to result in long-term improvements. Heavy rainfall in recent years has temporarily affected ocean salinity in some parts of the Region. Ocean pH is changing and is projected to decline in the future under climate change scenarios. Unlike the Outlook Report 2009, this assessment does not include consideration of pesticide accumulation.		↓				
🟩	**Nutrient cycling:** Most inshore areas of the southern two-thirds of the Region are exposed to elevated nutrient concentrations. Improved land practices are helping to reduce nutrient inputs.			↓		●	●
▧	**Ocean pH:** Decreasing ocean pH is likely to affect the ecosystem on a Reef-wide scale in the future.		↓			●	●
🟦	**Ocean salinity:** Recent floods have caused periods of reduced salinity in inshore areas and beyond.		↓			●	●

Grading statements

🟦 **Very good**	▧ **Good**	🟩 **Poor**	▩ **Very poor**
There are no significant changes in processes as a result of human activities.	There are some significant changes in processes as a result of human activities in some areas, but these are not to the extent that they are significantly affecting ecosystem functions.	There are substantial changes in processes as a result of human activities, and these are significantly affecting ecosystem functions in some areas.	There are substantial changes in processes across a wide area as a result of human activities, and ecosystem functions are seriously affected in much of the area.

Trend since 2009

↑ Improved
↔ Stable
↓ Deteriorated
– No consistent trend

Confidence

● Adequate high-quality evidence and high level of consensus
◐ Limited evidence or limited consensus
○ Inferred, very limited evidence

3.7.3 Ecological processes

Outlook Report 2009: Assessment summary
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.

2009 Grade	Current summary and assessment components	Assessment grade and trend				Confidence	
		Very good	Good	Poor	Very poor	Grade	Trend
▧	**Ecological processes:** At a Reef-wide scale, most ecological processes are considered to be in good condition but significant losses in coral cover and declines in ecosystem health in the inshore, southern two-thirds of the Region are likely to have affected some key ecological processes such as connectivity, reef building and recruitment.		↓				
▧	**Microbial processes:** There is limited information on microbial processes in the Region but they are responsive to changes in environmental conditions.		↔			○	○
▧	**Particle feeding:** The process of particle feeding is likely to have deteriorated given the decline in the abundance of coral and other particle-feeding species.		↓			○	○
🟦	**Primary production :** Elevated nutrients are likely to be affecting pelagic primary production in central and southern inshore areas. Some seafloor primary producers, such as seagrass, have declined; macroalgae abundance may have increased.	–				◐	◐
▧	**Herbivory:** Herbivorous fishes and green turtle populations remain stable. Declines in dugongs are likely to have affected herbivory in the Region.		↓			◐	◐

3.7.3 Ecological processes *continued*

2009 Grade	Current summary and assessment components	Assessment grade and trend				Confidence	
		Very good	Good	Poor	Very poor	Grade	Trend
🟩	**Predation:** Decreased predator populations affect the process of predation. No species is showing strong recovery and many remain at reduced numbers or their population sizes are poorly understood.			🟩 –		○	◐
🟦	**Symbiosis:** Symbiotic relationships are likely to have deteriorated in the southern two-thirds of the Region, reflecting the poorer overall condition of the ecosystem.		🟦 ↓			○	◐
Not assessed	**Recruitment:** Recruitment is reduced for many key species such as corals, some fishes, dugongs, some marine turtles and seabirds.			🟩		◐	
🟦	**Reef building:** Declines in coral cover in the southern two-thirds of the Region are likely to have affected the contribution of coral to the reef-building process.		🟦 ↓			○	○
🟦	**Competition:** There is little information about the multitude of competitive interactions.		🟦 ↔			○	○
🟦	**Connectivity:** Marine species and habitats remain connected; although connectivity with some terrestrial habitats is disrupted.		🟦 ↓			◐	◐

Grading statements

🟦 **Very good**	🟦 **Good**	🟩 **Poor**	🟩 **Very poor**
There are no significant changes in processes as a result of human activities.	There are some significant changes in processes as a result of human activities in some areas, but these are not to the extent that they are significantly affecting ecosystem functions.	There are substantial changes in processes as a result of human activities, and these are significantly affecting ecosystem functions in some areas.	There are substantial changes in processes across a wide area as a result of human activities, and ecosystem functions are seriously affected in much of the area.

Trend since 2009

↑ Improved
↔ Stable
↓ Deteriorated
– No consistent trend

Confidence

● Adequate high-quality evidence and high level of consensus
◐ Limited evidence or limited consensus
○ Inferred, very limited evidence

3.7.4 Terrestrial habitats that support the Great Barrier Reef

Outlook Report 2009: Not assessed

2009 Grade	Current summary and assessment components	Assessment grade				Confidence
Not assessed	**Terrestrial habitats that support the Great Barrier Reef:** Terrestrial habitats that support the Reef are generally in better condition in the northern catchment. However, habitats have been substantially modified in areas south of about Port Douglas, especially wetlands, forested floodplains, grass and sedgelands, woodlands and forests, and rainforests.			🟩		
		Very good	Good	Poor	Very poor	Grade
Not assessed	**Saltmarshes:** Some saltmarsh areas have been modified in the catchment.		🟦			◐
Not assessed	**Freshwater wetlands:** Freshwater wetlands remain intact in many areas, but many are functioning poorly.			🟩		◐
Not assessed	**Forested floodplains:** The area of forested floodplain has been halved and much of it is grazed.			🟩		◐
Not assessed	**Heath and shrublands:** Heath and shrublands are largely intact and well protected.	🟦				◐
Not assessed	**Grass and sedgelands:** Grasslands and sedgelands have been modified extensively in central and southern catchments, especially close to the coast.			🟩		◐

3.7.4 Terrestrial habitats that support the Great Barrier Reef *continued*

2009 Grade	Current summary and assessment components	Assessment grade				Confidence
		Very good	Good	Poor	Very poor	Grade
Not assessed	**Woodlands and forests:** There have been significant losses of woodlands and forests in much of the catchment, particularly in the Burdekin and Fitzroy regions.			🟩		◐
Not assessed	**Rainforests:** The greatest losses of rainforest have been in the Wet Tropics, Fitzroy and Burnett Mary regions. Wet Tropics rainforests have been protected since their inscription on the World Heritage list.		🟦			◐

Grading statements

Very good	Good	Poor	Very poor
🟦 All major habitats are essentially structurally and functionally intact and able to support all dependent species.	🟦 There is some habitat loss, degradation or alteration in some small areas, leading to minimal degradation but no persistent, substantial effects on populations of dependent species.	🟩 Habitat loss, degradation or alteration has occurred in a number of areas leading to persistent substantial effects on populations of some dependent species.	🟩 There is widespread habitat loss, degradation or alteration leading to persistent, substantial effects on many populations of dependent species.

Trend since 2009

New assessment for this report; no trend provided

Confidence

● Adequate high-quality evidence and high level of consensus
◐ Limited evidence or limited consensus
○ Inferred, very limited evidence

3.7.5 Outbreaks of disease, introduced species and pest species

Outlook Report 2009: Assessment summary
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.

2009 Grade	Current summary and assessment components	Assessment grade and trend				Confidence	
🟩	**Outbreaks of disease, introduced species and pest species:** Coral disease is being increasingly observed on the Great Barrier Reef and is predicted to increase in the future. There are few incidences of other disease and introduced species in the marine environment and they tend to be localised. Outbreaks may be becoming more frequent as ecosystem conditions decline. The overall assessment of 'poor' is due to the severity of outbreaks of crown-of-thorns starfish which seriously affect coral reef habitats on a large scale.			🟩 –			
		Very good	Good	Poor	Very poor	Grade	Trend
🟦	**Outbreaks of disease:** Disease has affected corals, green turtles, dugongs and the Queensland groper in recent years. Most outbreaks have not been recorded on a wide scale.		🟦 –			◐	○
🟩	**Outbreaks of crown-of-thorns starfish:** Growing evidence indicates ecosystem conditions may have resulted in more frequent outbreaks of crown-of-thorns starfish over the last 30 years across much of the Region. These have seriously affected the ecosystem.				🟩 ↓	◐	◐
🟦	**Introduced species:** Introduced marine species continue to be recorded in and adjacent to the Region. Introduced weeds have affected a number of islands within the Region.		🟦 –			○	○
🟦	**Other outbreaks:** Outbreaks of some other species are likely to have resulted from declining ecosystem conditions.		🟦 –			○	○

Grading statements

Very good	Good	Poor	Very poor
🟦 No records of diseases above expected natural levels; no introduced species recorded; pests populations within naturally expected levels.	🟦 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.	🟩 Unnaturally high levels of disease regularly recorded in some areas; occurrences of introduced species require significant intervention; pests outbreaks in some areas affecting ecosystem function more than expected under natural conditions.	🟩 Unnaturally high levels of disease often recorded in many areas; uncontrollable outbreaks of introduced pests; opportunistic pests seriously affecting ecosystem function in many areas.

Trend since 2009

↑ Improved
↔ Stable
↓ Deteriorated
– No consistent trend

Confidence

● Adequate high-quality evidence and high level of consensus
◐ Limited evidence or limited consensus
○ Inferred, very limited evidence

Healthy connections between marine and freshwater habitats are important to the Reef ecosystem © Matt Curnock

3.7.6 Overall summary of ecosystem health

The past decade of extreme weather events, combined with the continuing poor condition of key processes such as sedimentation and nutrient cycling, have caused the overall health of the Great Barrier Reef ecosystem to deteriorate since 2009. While improved land management practices are beginning to reduce the amount of nutrients and sediments leaving the catchment, there is likely to be a long lag time between these improvements and reductions in pollutants flowing into the Region, and again between that and improvements in related marine processes.

The decline in ecosystem health is most pronounced in inshore areas of the southern two-thirds of the Region. In contrast, the continuing good and very good condition of almost all processes in the northern third of the Region and in offshore areas means that the ecosystem in these areas continues to be healthy. Ecosystem processes are integral to the attributes recognised in the world heritage listing of the Great Barrier Reef. The deteriorating condition of many is likely to be affecting its outstanding universal value.

One indicator of declining ecosystem health is that crown-of-thorns starfish outbreaks are becoming more frequent. Rather than experiencing outbreaks in a natural cycle of about every 50 to 80 years, the Reef has been affected by three in the past 50 years and a new outbreak has begun. Crown-of-thorns starfish have been a major cause of coral loss in recent decades. There is growing evidence of a link between outbreaks and deterioration in the process of nutrient cycling. The overall grade of ‘good’ for outbreaks of disease, introduced species and pest species is borderline with ‘poor’ due to the severity of crown-of-thorns starfish outbreaks in recent years.

Sea temperature is increasing. While other environmental conditions (for example cloud cover and wind) have meant periods of elevated temperature have not been as prolonged as those in the late 1990s and early 2000s, the trend of increasing temperatures places the ecosystem at serious risk into the future. Other processes likely to have a Reef-wide influence on ecosystem health, such as ocean pH and sea level, are also expected to deteriorate into the future.

Terrestrial habitats that support the Great Barrier Reef ecosystem are generally in very good condition north of Port Douglas. Further south, in the bulk of the Region’s catchment, all supporting habitats have been substantially modified. This has affected connectivity and the capacity for these habitats to support marine habitats and species.

Knowledge of the key variables that contribute to some physical and chemical processes — such as sedimentation, sea temperature, nutrient cycling and freshwater inflow — is improving. There remains a poor understanding and almost no monitoring of many others, especially ecological processes such as connectivity, competition, predation and microbial processes. Monitoring pest introductions remains a gap.

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Heritage values

CHAPTER 4

'an assessment of the current heritage values ...' of the Great Barrier Reef Region, Section 116A(2)(a) of the *Great Barrier Reef Marine Park Regulations 1983*

2014 Summary of assessment

Heritage values not assessed in 2009 — trend not provided

Indigenous heritage values	Traditional Owners with connections to the Region maintain their cultural practices and customs. Places of Indigenous heritage values have not been systematically identified and many have deteriorated, especially around developed areas and on islands. Some species of cultural significance are under pressure. Story, language and songlines are being affected by activities in the Region.	Poor
Historic heritage values	There is good understanding and recording of some aspects of historic heritage in the Region, for example known historic shipwrecks, a small number of World War II features and lightstations. Heritage values are being maintained or restored at heritage-listed lightstations. Most other places of historic significance are poorly recorded and their condition is not well understood.	Good
Other heritage values	The Region's social and scientific heritage is being maintained. The Great Barrier Reef continues to have great scientific significance. People continue to value and connect with its environment and its natural beauty is widely appreciated. Declines in environmental condition in the central and southern inshore areas have reduced underwater aesthetic values.	Good
World heritage values and national heritage values	The Outstanding Universal Value of the world heritage property remains in good condition, however the overall condition of some key attributes is poor and many have deteriorated since the property's listing in 1981. Those related to coral reef and seagrass meadow habitats, marine turtles, seabirds and dugongs are assessed as being in poor condition overall. The Region remains a globally outstanding example of an ecosystem that has evolved over the millennia. The natural beauty of most of the Region remains, however its underwater aesthetic value has declined in central and southern inshore areas. External pressures are affecting the property's integrity.	Good
Commonwealth heritage values	The five places in the Region that are included on the Commonwealth Heritage List retain the values for which they were listed. The Shoalwater Bay Military Training Area and the four historic lightstations have been well recorded, retain their integrity and are in good condition. Low Island retains its importance as part of Indigenous tradition.	Good
Natural heritage values	Most of the Region's natural heritage values remain in good condition, but some are in decline, especially in its southern two-thirds. Values in poor condition include coral reefs and corals, seagrasses, seabirds, sedimentation, nutrient cycling and sea temperature. Populations of some iconic species such as dugongs and marine turtles are also in poor condition.	Good

Full assessment summary: see Section 4.8

< Photograph © Chris Jones

Heritage values

4.1 Background

An assessment of heritage values of the Great Barrier Reef Region (the Region) was introduced as a legislative requirement for the Great Barrier Reef Outlook Report in late 2013. It was not part of the first Outlook Report in 2009.

The requirement reflects the 2008 amendment of the *Great Barrier Reef Marine Park Act 1975* (the Act) to include protection and conservation of the heritage values of the Region in its main object and responds to a 2012 recommendation by the World Heritage Committee.

As defined in the Act, for the purposes of the Outlook Report, the heritage values of the Region include:

- Indigenous heritage values: the heritage values of a place that are of significance to Aboriginal and Torres Strait Islander persons in accordance with their practices, observances, customs, traditions, beliefs or history
- other heritage values: a place's natural and cultural environment having aesthetic, historic, scientific or social significance, or other significance, for current and future generations of Australians
- world heritage values: the natural heritage and cultural heritage of a property that is internationally recognised as being of outstanding universal value
- national heritage values: the values of a place that are of national significance as recognised through placement on the National Heritage List
- Commonwealth heritage values: the values of a place that are specified in its placement on the Commonwealth Heritage List.

The values of the Region encompassed by these legally defined categories are interconnected and overlapping and there are many ways to group them.

In this chapter and throughout the report, the Region's heritage values are grouped into:

- Indigenous heritage values
- historic heritage values
- other heritage values (comprising social, scientific and aesthetic heritage values)
- world heritage and national heritage values
- Commonwealth heritage values
- natural heritage values (assessed in Chapters 2 and 3 and summarised in Section 4.7).

4.2 Current state and trends of Indigenous heritage values

Indigenous heritage recognises the heritage of Aboriginal and Torres Strait Islander peoples who are the First Australians and the Traditional Owners of the Great Barrier Reef. It is an important element in Indigenous custom and its preservation ensures continued recognition and respect for past generations of Traditional Owners and the ancestral beings that shaped the land, seas and waterways.[1]

Indigenous heritage is a unique, dynamic and diverse living heritage. Traditional Owners express their cultural heritage through their relationships with country, people, beliefs, knowledge, lore, language, symbols, ways of living, sea, land and objects. All of these arise from Indigenous spirituality and the responsibility of Traditional Owners to maintain their connection to their heritage through customary practices. Many traditional cultural practices include plants, animals and the environment, making nature inseparable from cultural identity.

'The sea, its natural resources and our identity as Traditional Owners, are inseparable... Our ancestors have hunted and fished in this sea country since time immemorial...'[2]

The strong ongoing links between Traditional Owners and their sea country is one of the attributes recognised as contributing to the outstanding universal value of the Great Barrier Reef as a world heritage property.

There are more than 70 Traditional Owner groups who are responsible for maintaining the cultural values of their land and sea country in and adjacent to the Region. This includes a small number of Torres Strait Islander groups who express traditional and spiritual connection in the northernmost area of the Region. While Aboriginal and Torres Strait Islander peoples have some common heritage values, there are also many unique expressions of heritage for each.

Throughout this chapter Indigenous heritage values are grouped into four broad components:

- cultural practices, observances, customs and lore
- sacred sites, sites of particular significance and places important for cultural tradition
- stories, songlines, totems and languages
- Indigenous structures, technology, tools and archaeology.

While this chapter presents information on Indigenous heritage values under discrete headings, in reality they cannot be separated. In addition, the natural heritage values described in Chapters 2 and 3 are fundamental to Traditional Owners and their connection to land and sea country. All values are connected and interrelated and the descriptions of each value should be viewed in this context.

Traditional Owners are maintaining their cultural practices and transferring them to future generations.

4.2.1 Cultural practices, observances, customs and lore

Cultural practices, observances, customs and lore are comprised of intangible features such as skills, folklore, rituals, religious beliefs and intellectual traditions, passed down from generation to generation. They are an intrinsic part of custom and continue to be observed by Indigenous people in their sea country.

Throughout the Region, Traditional Owners maintain their cultural practices and customs and pass information and knowledge across generations. Practices and customs are an integral part of their sea country management. For example, controlling use of and access to sea country estates by Traditional Owners regulates resource use based on cultural practices and belief systems. It is consistent with the recognition of traditional customs, practices and lore.

Seasonal and cultural use of marine resources and the opening or closing of harvesting seasons according to ecological events (for example, flowering of particular plants or the arrival of migratory bird species) continue to be practised by Great Barrier Reef Traditional Owners.[3] Important skills and traditional ecological knowledge are passed down from one generation to the next, enabling Aboriginal and Torres Strait Islander peoples to follow the same seasonal patterns as their ancestors. The transfer of these skills and knowledge means different resources continue to be exploited at different times of the year.[4]

Indigenous heritage values associated with these sacred rocks include protection over sea country areas
Photograph by Kathi Gibson-Steffensen

4.2.2 Sacred sites, sites of particular significance and places important for cultural tradition

Sacred sites, sites of particular significance and places of cultural tradition are tangible aspects of the Region's Indigenous heritage. Sacred sites are significant heritage places for Indigenous people and their enduring traditions. For example, they may be creation or resting places for ancestral spirits, places that contain healing water and medicinal plants, burial grounds, traditional tracks of Aboriginal peoples' movements or sites associated with special events.[5]

Many sites of significance are areas of great importance for the conservation of biodiversity across land and sea country, and many communities are unable to separate the reasons for protecting the spiritual connections between people and the earth from the reasons for conserving biodiversity. In most cases, natural and cultural heritage values of sites form a continuum rather than being separate entities.[6]

As on land, sea country contains evidence of events that occurred during the Dreaming through which all geographic features, animals, plants and people were created. Sacred sites often relate to creation events, Dreaming tracks or songlines travelled by spiritual beings during the creation period. A defining feature of sacred natural sites is that Aboriginal people have known about and cared for them since time immemorial. Aboriginal and Torres Strait Islander peoples have custodial responsibilities as part of their lore which connect them to country, thereby ensuring the maintenance of spiritual, cultural, biological and other values of such sites.[6]

There are sacred sites, sites of particular significance and places important for cultural tradition along the length of the Region, often linking land and sea. Some examples include:

- There are fish traps on Hinchinbrook Island, a system of stone-walled pools that flood at high tide, trapping fish as the tide goes out.
- Worrungu Bay (near Cape Upstart) is a significant area for the Juru people. The bay is a women's meeting area. Traditionally, Juru women collect shellfish from the swamp and walk to the sand dunes to cook them on a fire.[7]
- Cape Hillsborough National Park is known to contain burial grounds of the Yuibera clan and is a sacred place for Aboriginal spirits. Mangrove areas along its coast are still used for men's ceremonies in the early wet season and the eastern area of the beach contains fish traps that can only be seen during a very low tide.[8]

Some known sites of cultural significance are under pressure, including from coastal development and severe weather events.

It can be predicted that the Region contains significant underwater Indigenous sites[9] from tens of thousands of years ago when sea levels were up to 130 metres lower than current levels and past generations of Traditional Owners lived and moved over parts of what is now the Great Barrier Reef seafloor. Such sites can be expected to provide unique insights into past peoples' uses of the land. None of these have yet been discovered. The previous occupation of the continental shelf is reflected in some Aboriginal place names for marine areas. For example, for speakers of Yidiny, just south of Cairns, there is a place halfway between Fitzroy Island and King Beach called *mudaga* (pencil cedar) after the trees which grew there — the area is now completely submerged.[10]

There are many places, especially in coastal systems and on islands, where there is pressure on sacred sites and other sites of cultural significance. This is particularly around areas of development or intensive use and those exposed to severe weather events. Other sites are intact and are being managed by Traditional Owners.

4.2.3 Stories, songlines, totems and languages

Expressive social activities such as stories, songlines, totems and languages, as well as music and dance, are part of Indigenous heritage and everyday life and are an integral aspect of ceremonies.[3] For Aboriginal and Torres Strait Islander peoples all that is sacred is in the land, water, air and sea. Knowledge of the environment and the responsibility to maintain

The estuarine crocodile is a totem of some Traditional Owners
Photograph by S. Whiting

all living species, places or objects in a sustainable manner is passed down the generations through these mediums. Stories, songs, dance, dress, art and language connect people to a place or time. They provide history, learning and perspective.

Some coastal activities and uses in the Region are affecting stories, songlines, totems and languages.

Examples of places in the Region that have important stories associated with them include:

- The Kuku Yalanji people believe the Low Islets and Snapper Island (*Minya Gambyi*), the mouth of the Daintree (*Binda*) and Cape Kimberley (*Baku*) were once part of a united landmass that became separated during the Dreamtime. These three sites would be visited regularly by Traditional Owners to maintain contact with important Dreaming sites and stories.[11] This significance to Traditional Owners as part of their Dreaming is recognised by the inclusion of traditional values in the listing of Low Island and Low Islets Lightstation on the Commonwealth Heritage List.
- Lizard Island is a sacred place, known as *Jiigurru* (or *Dyiigurra*), to the Dingaal (or Dingiil) Aboriginal people of Cape York Peninsula. The group of islands was formed during the Dingaal Dreamtime. The group of islands is thought to be a stingray, with Jiigurru being the body and the other islands forming the tail.[12]

Story, language, and songlines are affected by a range of activities that disrupt flow and connections between areas. For example, Clump Point near Mission Beach is a culturally important story place with part of the story involving the shape of the bay and headland. Changes due to coastal development mean the storyline is now broken.[13] Also, ship groundings are likely to have affected the cultural heritage of Piper Reef, an important story place for its Kuuku Y'au Traditional Owners.

Some plants and animals of particular significance — referred to as 'cultural keystone species' — play a fundamental role in Traditional Owner culture, including through diet, materials, medicine, totems and stories.[14]

Some Aboriginal and Torres Strait Islander peoples can be identified by their totems, which can be any animal, plant or object. Examples include birds, marine turtles, dugongs, sharks, crocodiles and fishes.[15] Totems are an important part of cultural identity and they can be incorporated in song, dance, music and on cultural implements.[15] Most Aboriginal and Torres Strait Islander people's customs forbid eating the animal that is their totem, while some make exceptions for special occasions such as ceremonies.[15] For other groups and individuals, their totems are their favoured form of sustenance.

In the Region, populations of many cultural keystone species have been significantly reduced and are under pressure, especially in areas south of Cooktown — examples include dugongs, green turtles, some sharks and some bony fish (see Chapter 2). This in turn affects the Region's Indigenous heritage values.

When Jajikal Warra Traditional Owner Marie Shipton was asked about seeing marine turtles nesting along the beaches of her sea country between Cedar Bay and Cape Tribulation, she replied "*... no we don't anymore... we used to have a lot of turtle and dugong but it's very few now, but we don't know where they're gone".*[16]

4.2.4 Indigenous structures, technology, tools and archaeology

Indigenous structures, technology, tools and archaeology are perhaps the more well-known features of Indigenous heritage. While some structures and sites are located within the Region, many that are located on the adjacent coast and islands are important to the Region's heritage significance.

Tools, implements and technologies reflect the geographic location of each group and their trading interactions with other groups. There are distinct differences in the materials used in implements for daily activities (such as hunting, cooking and collecting) as people used the resources available to them. For example:

- Mandingalbay Yidinji Traditional Owners, like other coastal Aboriginal groups in the Cairns area, developed a wide range of technologies from local material for use in hunting, fighting, making substantial shelters, baskets, fish traps and tools. Well into the twentieth century, single outrigger canoes were used extensively for fishing, hunting and travelling.[17]
- Nywaigi people from the area south of the Herbert River have found many stone axes and grinding stones on their country that people had been using for thousands of years. The stones were traded with neighbouring tribes from the mountains where the stones originated.[7]
- Traditional Owners of the Whitsunday Islands, the Ngaro peoples, built sturdy three-piece bark canoes that were capable of open sea journeys.[17]

Archaeological sites in and adjacent to the Region include:

- occupation (residential) sites: areas containing stone tools, food remains, ochre, charcoal, cooking stones and shells

- middens: deposits of food refuse, usually shellfish
- stone quarries: areas known to have produced high-quality stone tools
- grinding grooves and stone chipping areas: evidence of tool making or food processing found on flat sections of rock
- fish traps: constructed to harness the tides in catching fish
- rock art (which often tells Dreaming stories and sometimes provides pictorial evidence of past rituals central to the lives of Traditional Owners)
- scarred trees as a result of bark being removed for food or to make canoes, water containers, shields or huts.

Archeological sites document past Aboriginal use of the Region and its islands and coast. For example, research shows that the Ngaro people have inhabited the Whitsundays for at least the past 9000 years. Evidence of occupation includes numerous fish traps, a stone quarry and rock art at Nara Inlet on Hook Island. Archaeological sites also show the connections between coastal and hinterland Aboriginal people, such as trade links.

Ancient rock art sites help chronicle the history and heritage of Indigenous people, while oral histories transferred through time deliver traditional knowledge and understanding about tools or technology. The rock art at Cape Ferguson, which has been documented by the Bindal Traditional Owners from the Townsville area, is an example of knowledge and information transfer.[7] The rock art in the Flinders group of islands provides evidence of sightings by Aboriginal people of early sailing ships travelling through the Region.

Indigenous structures, tools, technologies and archaeology, although well known to Traditional Owners, have not yet been systematically identified by managing agencies and therefore may be vulnerable to coastal development and other land use activities. They are also vulnerable to rises in sea level and severe weather events. Some specific sites, such as the Hinchinbrook Island fish traps, are managed by the Traditional Owners of the area.

Indigenous structures and archaeology have not been systematically identified; many are under pressure.

Tools and implements are part of Traditional Owner cultural heritage

4.3 Current state and trends of historic heritage values

For the purposes of this report, historic heritage values relate to the occupation and use of the Region since the arrival of European and other migrants. They illustrate the way many cultures of Australian people have modified, shaped and created the cultural environment of the Region. By its very nature, historic heritage will continue to evolve, representing the flow of history and changing community perceptions.[18] While some specific aspects of the Reef's historic heritage have been well documented, knowledge of many historic places or events is limited.

The following summary of the Region's historic heritage values is grouped into four broad components:

- historic voyages and shipwrecks
- historic lightstations
- World War II features and sites
- other places of historic significance.

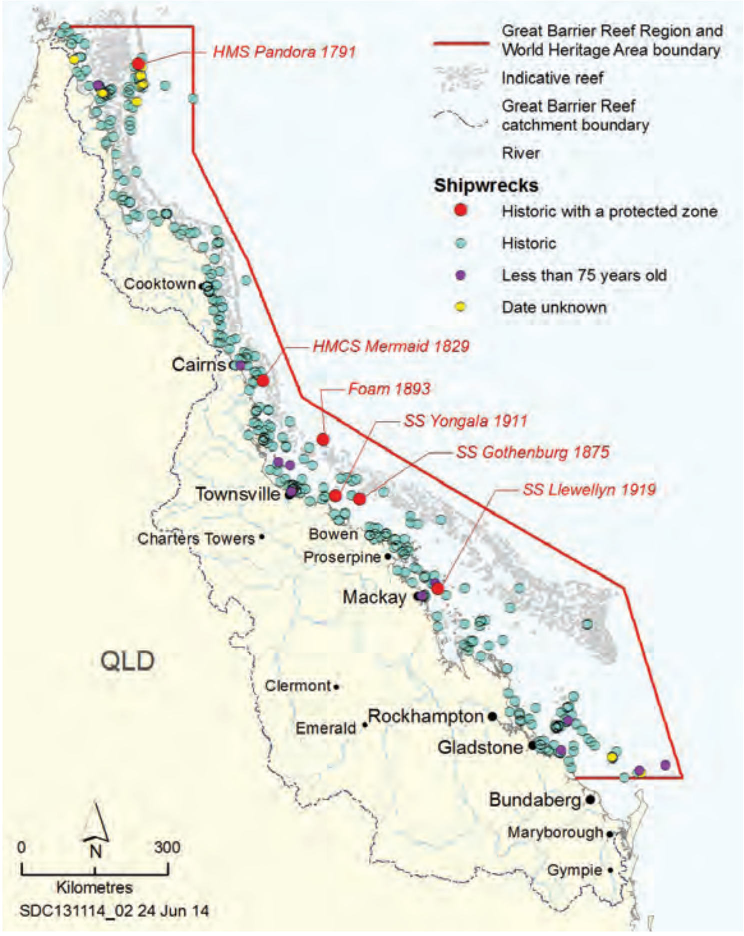


Figure 4.1 Shipwrecks
There are several hundred shipwrecks in the Region which are over 75 years old, including six with a declared protected zone which may only be entered with permission. Source: Queensland Department of Environment and Heritage Protection

4.3.1 Historic voyages and shipwrecks

As an island nation, ships and shipping activity have played a pivotal role in Australia's history. The north-east coast is an unavoidable part of the route between Australia's eastern ports and much of the rest of the world, forcing ships to travel either inside or outside the Great Barrier Reef. The hazards of operating ships through the maze of reefs have amplified the historical maritime significance of the Region.

A number of significant voyages of discovery were made through the Great Barrier Reef during the colonial period of Australia's history, especially to chart the coast and reefs. Some of the more significant voyages are summarised in Table 4.1.

Throughout Australia's history, navigating the Great Barrier Reef has been recognised as a treacherous undertaking, especially during the era of sail when accurate charts were not available. Of the more than 1300 historic shipwrecks known to be in Queensland waters[19], the majority are likely to be located in the Region (Figure 4.1). Research continues to locate known wrecks in the Region and new wrecks are discovered regularly.

Shipwrecks and their associated relics older than 75 years (termed historic shipwrecks) are protected through the *Historic Shipwrecks Act 1976* (Cth), regardless of whether their location is known. More recent shipwrecks may also be declared as historic and protected under the Act if they are considered significant. Historic shipwrecks are protected for their heritage values and maintained for recreational, scientific and educational purposes. Most historic shipwreck sites can be accessed, but relics must not be removed from the wreck or the surrounding site and the physical fabric of the wreck must not be disturbed, for example through anchor damage.

Table 4.1 Historic voyages of discovery
Some of the voyages of great significance to Australia's early colonial history travelled through the Great Barrier Reef.

European explorer	Date	Significance
Louis de Bougainville	1768	First European to sight the Great Barrier Reef
Lieutenant James Cook	1770	First European to navigate inside the Great Barrier Reef up to Lizard Island where he left the inner Reef to avoid what he called the 'labyrinth'
Commanding Lieutenant William Bligh	1789	After a mutiny on HMB *Bounty*, Bligh and 18 crew sailed in a small boat from Tofua in the South Pacific to Timor. He entered the Great Barrier Reef at Bligh Boat Entrance and sailed through it to the north
Captain Edward Edwards	1791	Charged with finding and returning the mutineers of the *Bounty*, his vessel HMS *Pandora* was wrecked in the northern Great Barrier Reef
Lieutenant Matthew Flinders	1801	First to circumnavigate Australia, though he avoided much of the Great Barrier Reef by going on its outside from Flinders Passage, south of Townsville
Lieutenant Phillip Parker King	1817–1822	Charted the substantial area of the inner Reef passage avoided by Cook and Flinders

Many significant voyages of discovery sailed through the Region.

There are six historic shipwrecks in the Region for which a protected zone has been declared under the Historic Shipwrecks Act (Table 4.2). A protected zone is declared where additional protection is needed to reduce the risk of damage to a significant historic shipwreck. Sizes vary from 50 to 797 metres radius around the wreck. A protected zone can only be entered with permission under the Act.

Two of the historic shipwrecks are well surveyed and recorded.

While the wrecks of the HMS *Pandora* and the SS *Yongala* are well documented, there is no structured monitoring of the condition of any of the historic wrecks within a protected zone, or any of the other wrecks in the Region.

Table 4.2 Historic shipwrecks for which a protected zone is declared

Under the Commonwealth Historic Shipwrecks Act, a protected zone has been declared around six historic shipwrecks in the Region. The zone can only be entered with permission.

Ship	Wrecked	Location	Significance
HMS *Pandora*	1791	Pandora Entrance near Raine Island	Example of British naval vessel and fittings from the Georgian era. Associated with an iconic maritime event (mutiny on the *Bounty*). Exemplary evidence of early Pacific exploration by the British including extensive collections of 'curiosities' representing Polynesian heritage.
HMCS *Mermaid*	1829	Flora Reef	Used by the first Australian-born explorer, Lieutenant Phillip Parker King, to chart the inner Barrier Reef route and large parts of the Australian continent. Pivotal to the development of northern Australian ports as a supply ship. Representative of early colonial exploration within the Great Barrier Reef.
SS *Gothenburg*	1875	Old Reef	Representative of three-masted iron screw steamer used for coastal trade in the late nineteenth century. Loss of 103 people. Carried £43,000 of gold which was recovered by a diver in standard dress (brass helmet and canvas suit), making it also significant in the history of diving.
Foam	1893	Myrmidon Reef	Involved in 'blackbirding' of South Sea Islander peoples, a significant practice in establishing north Queensland agriculture, providing cheap labour. Contains evidence of this era, including trade items.
SS *Yongala*	1911	off Cape Bowling Green	Representative of a steam vessel involved in early twentieth century coastal trade, such as mail, freight and passenger transport. Wrecked in a cyclone with loss of 122 lives. Strong link to north Queensland communities with living first degree relatives.
SS *Llewellyn*	1919	off St Bees Island	Representative of a vessel involved in early twentieth century coastal trade. Recently discovered, not yet fully surveyed or assessed.

There is no structured monitoring of wrecks.

Anchor of the HMCS Mermaid on Flora Reef
© Silent World Foundation, photograph by Xanthe Rivett

Double boilers of the SS Gothenburg
© Queensland Parks and Wildlife Service

Figure 4.2 Early lighthouses
Thirteen lighthouses were installed in or adjacent to the Great Barrier Reef before 1900. While some are still in place, others have been removed. Those on Low Isles, Dent Island, North Reef and Lady Elliot Island are within the Region and are on the Commonwealth Heritage List.

4.3.2 Historic lightstations

The Region's historic lightstations, comprising the lighthouse, accommodation and other infrastructure, are associated with the shipping and navigational history of the Great Barrier Reef.

There is a range of lightstations along the Reef on Commonwealth and Queensland islands and along the coast. They include Commonwealth and state heritage-listed lightstations built in the 1800s (Figure 4.2), 'concrete tower' aids to navigation dating from between the 1920s and the 1960s, and 'steel frame' aids to navigation. The locations and values of the listed lightstations, including the lighthouses and ancillary structures, are generally well recorded.[21,22]

Four lightstations located within the Region — Low Isles, Dent Island, North Reef and Lady Elliot Island — are listed Commonwealth heritage places (Section 4.6.2). They are important examples of the technically innovative and economically constructed navigational facilities built by Queensland authorities between 1859 and 1901. They are reminders of the early development of Queensland coastal areas after the colony's separation from New South Wales. Each of these lightstations remains in good and stable condition and is generally well maintained.

There are some other aids to navigation originally built in the 1920s and 1930s on islands within the Region. These are maintained as working facilities by the Australian Maritime Safety Authority. While not heritage-listed, they demonstrate a phase in the evolution of aids to maritime navigation through the Reef.

Pine Islet lightstation, built in 1885 in the southern Great Barrier Reef, has fallen into major disrepair with some structures collapsing.

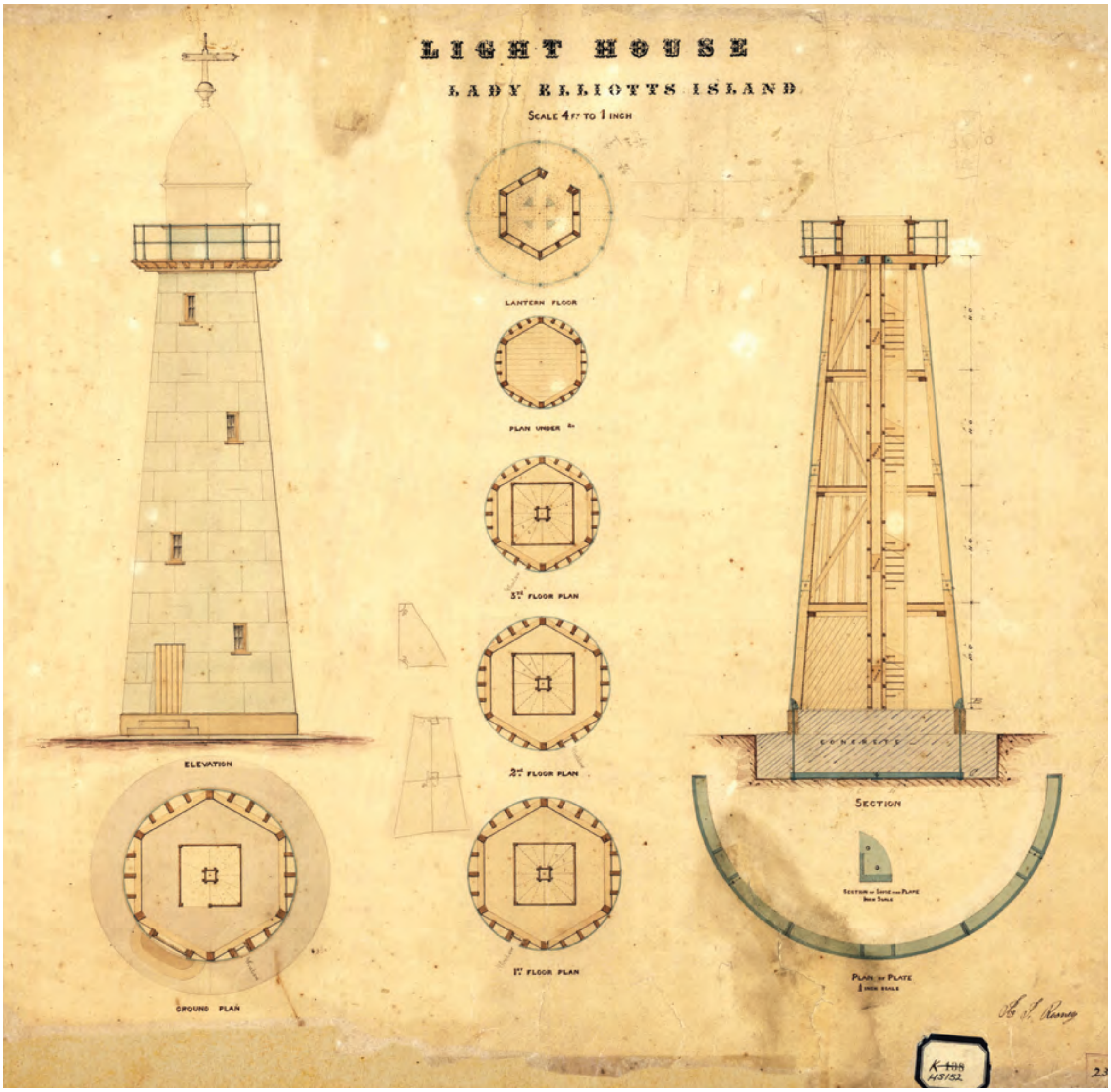
Heritage values are well recorded and maintained at heritage-listed lightstations.

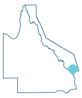
While not a lighthouse, the historic navigation beacon on Raine Island, a Queensland island in the northern Great Barrier Reef, is a significant historic structure adjacent to the Region. It is on the Register of the National Estate and the Queensland Heritage Register. Built in 1844 by a party of convicts transported to the island by HMS *Bramble* and HMS *Fly*, the beacon is significant as a monument in Queensland's maritime landscape and assisted the colony's early economic development. Conservation works on the beacon were carried out in 1988.[21]

Evolution of the Dent Island lightstation

There was significant maintenance of Dent Island lightstation in 2013–14.

The Dent Island lightstation is an important example of the historical development of maritime aids to navigation in Australia and was placed on the Commonwealth Heritage List in 2004. The lighthouse, erected on the island in 1879, was one of a series of 12 lighthouse towers of a distinctive type, built between 1873 and 1890. These timber-framed towers clad with riveted iron were designed by officers of the Queensland colonial government, to meet the particular needs of the colony, in a form that was not used anywhere else in the world. The lighthouse is now fitted with solar-powered lighting equipment and operates automatically as a part of the national network of navigation aids. Near the lighthouse tower are two houses, a workshop, a derrick crane, a winch house, a trolley way, and a fowl house. All are privately leased. Significant works were carried out on these buildings during 2013–14 to prevent further degradation. A heritage management plan for the lightstation was registered in January 2014.





For Lady Elliot Island, a new composite form of construction was developed, combining the economy of timber framing with the weather-tightness and durability of iron plating. This contract drawing for the lighthouse was signed in 1872.
Source: National Australian Archives: J2775, HS152

4.3.3 World War II features and sites

The Region was part of the Pacific theatre of World War II and several major support facilities, including airbases from which pivotal battles were launched, were on the adjacent coast. Many significant features and sites from that period remain in the Region. Incomplete databases suggest that more than 140 submerged aircraft wrecks survive representing most known aircraft wrecks in the Region. These span a wide inventory of World War II aircraft including Kittyhawks, Catalinas, Dakota, B-25D Mitchells and Beaufort Bombers. Other World War II features and sites include shipwrecks, support structures such as refuelling barges, unexploded ordnances and structures on islands. While some of these features and sites have been identified, most are yet to be located and little is known of their condition.

While many World War II features and sites have been identified, little is known of their condition.

Some of the aircraft wrecks are the resting place of service personnel. It is estimated that over 150 allied air crew (including from Australia, America and Holland) could have gone missing in action in planes wrecked and sunk in the Region.[23]

In 2011, the wreck of a Catalina PBY 5 flying boat, A 24 24, was found off Bowen. The Royal Australian Air Force acknowledges this wreck as the resting place of the 14 personnel who went missing-in-action in the wrecking incident. The wreck of another Catalina, A 24 25, was discovered in 2013 off the Frankland Islands south of Cairns and may hold the remains of a further 11 personnel. An aerial heritage survey conducted in January 2014 located three World War II P39 Airacobra aircraft wrecks in various states of deterioration in shallow water along the coast of the Region.

Unlike shipwrecks, there are no formal arrangements to protect aircraft wrecks other than the provisions of the Great Barrier Reef Marine Park Act. Some aircraft, such as the Catalina off the Frankland Islands, are protected to some extent because they are located in a Marine National Park (green) Zone, but there has been some degradation and damage. Catalina A 24 24 off Bowen is located within a General Use (light blue) Zone and has suffered damage from trawling, anchoring and as a result of line fishing.

Catalina A 24 25 motor, off the Frankland Islands
© Kevin Coombes

Airacobra wreck, Margaret Bay

4.3.4 Other places of historic significance

Other places of historic significance include sites where historic events occurred. Examples range from Endeavour Reef where Captain Cook ran aground over two centuries ago to Ellison Reef, a pivotal location in the modern fight to protect the Reef. In 1967, a team of volunteers surveyed Ellison Reef to prove that it was 'alive' in order to protect it from being mined for limestone. The campaign raised the national profile of the Great Barrier Reef and a subsequent Royal Commission paved the way for development of the Great Barrier Reef Marine Park Act and Authority.[24]

Most places of historic significance in the Region are either not recorded or their records have not been recovered. Their condition is not well understood.

Other places of historic significance are poorly recorded and their condition is not well understood.

While most Great Barrier Reef islands are not within the Region, they have played a major role in its history, including places connected with Reef identities such as the author and naturalist Edmund Banfield on Dunk Island and Mrs Watson, an early pioneer and folk hero, on Lizard Island. Places that illustrate changes in use of the Great Barrier Reef are also significant — from early guano mining on islands, green turtle factories on islands, to limestone and granite mining, and oil exploratory leases.[24]

Green Island and its surrounding reef have been a popular tourist site for over 100 years, with organised pleasure cruises since 1890 and a passenger ferry since 1924.[25] Other locations such as Magnetic Island, Low Isles and Newry Island all played significant roles as tourism evolved in the Region.

4.4 Current state and trends of other heritage values

4.4.1 Social heritage values

In accordance with the Act, the definition of heritage values includes reference to '*a place's natural and cultural environment having... social significance... for current and future generations of Australians'.*

For Traditional Owners, the Region's natural and cultural environment has inherent social significance (Section 4.2). This section describes and assesses the range of other social heritage values of the Region.

Many aspects of the Region's natural and cultural environment have social significance. The perception of significance varies according to societal attitudes (see Section 6.2.4), as well as an individual's personal perspectives and their relationship to the Reef. The Reef has social significance nationally and internationally as demonstrated by continued global interest in its protection. At the broadest level, most values of social significance can be traced back to the extraordinary beauty, biodiversity, natural abundance and remoteness of the Region. Its social value can be independent of people visiting the area, but is augmented by the personal experiences they have had there.

From the beginnings of European exploration and settlement, navigation and use of the Reef have presented significant challenges and opened up new horizons — playing a role in shaping Queensland society. The ways in which people have responded to the challenges and taken up the opportunities have added to the social significance of the Reef. Examples include the intrepid journeys of early explorers; the discoveries and descriptions of the Reef ecosystem by early scientists; the experiences of hardship and survival, such as those of shipwreck survivors; and early interactions with the Reef's Traditional Owners.

The wonder of the Reef and a history of personal experiences have built its social significance.

In addition, the history of commerce on the Reef has resulted in some places of social significance. Examples include the Cod Hole — an iconic dive site and one of the first parts of the Great Barrier Reef to receive marine park protection; John Brewer Reef — the site of the only ever floating hotel in the Region; and Whitehaven Beach — a spectacular and high-profile white sand beach in the Whitsundays.

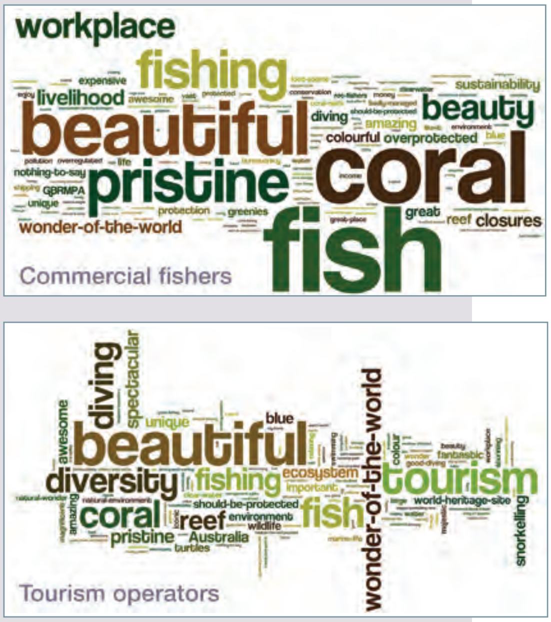
On a more personal level, particular aspects of the Region's natural and cultural environment (such as a place, a species or an activity) can be of social significance to an individual, a family or a community. This may be as a result of employment, stewardship activities, recreational experiences, or family, personal or spiritual connections. This social significance builds personal connection to the Reef.

Continued education about and interpretation of the Reef and its history, combined with its ongoing use by generations of people, act to preserve and enhance the social significance of its natural and cultural environment.

Human wellbeing and Reef connections

The Great Barrier Reef plays an important role in community life. Human wellbeing — a state of happiness, good health and prosperity — is inextricably linked to environmental health.[26] Many individuals and communities have strong connections with the Reef, through culture, occupation, or familiarity, and these connections contribute to their wellbeing.[27] In a 2013 national survey, the Great Barrier Reef was rated as Australia's most inspiring landscape by about 43 per cent of respondents, while 86 per cent feel proud that the Great Barrier Reef is a world heritage area.[28] For those who are part of Reef-dependent industries, the connection is particularly strong with their work forming a core of the way they think about themselves and their role in society. For example, commercial fishers and marine tourism operators depend on the Reef for their livelihoods, but their connections to the Reef are often stronger than economic dependency.[29,30] One commercial fisher captures this connection:

> *"... it's an income to me but there's also those sort of things... go out and swim all day, watching the whales. I'm just as much of a kid going out there and seeing a couple of humpbacks jumping around with the calf as catching a hundred mackerel for the day."*[31]



Values held by commercial fishers and tourism operators about the Great Barrier Reef. The bigger the word, the more often it was recorded.
Source: Tobin *et al.* 2014[29], Curnock *et al.* 2014[30]

4.4.2 Aesthetic heritage values

Over recent decades, some of the local-scale aesthetic values of the Great Barrier Reef and its coastal landscapes have been recognised and documented, for example through development of Coastal Management Plans.[32] Until recently, there has been little focused study of the aesthetic values of the Region as a whole. In 2013 they were broadly defined and assessment methods were documented.[33] The outcomes informed this section.

It is recognised that culture, knowledge, expectations and past experience mediate peoples' perceptions and experiences. As a result, aesthetic responses are linked to both the characteristics of an environment and culturally or personally derived preferences. For natural features such as the Great Barrier Reef, aesthetic values are generally associated with the outstanding natural values and attributes of the environment.[33]

The environmental attributes of the Region identified as enhancing aesthetic value include: the Reef as an entity; coral reefs; continental islands; beaches; coral cays; water (clarity, calmness, intensity of colour);

marine animals (abundance, diversity, colour, size); blue holes; lagoon floors; mangroves; seagrass meadows; shoals; cliffs and rocky shores; bays; estuaries; rainforest; birds; and butterflies.[33]

The experiential attributes of the Region that enhance aesthetic value were identified as: beauty, naturalness, tranquillity, solitude, remoteness, discovery and inspiration.[33]

The aesthetic values of the Great Barrier Reef are experienced and described from a variety of perspectives:

- Panoramic: the Great Barrier Reef from above, including remotely from space, from the air or high lookout points. This perspective shows the Reef as a pattern of waters, reefs, cays and islands, and as a vast landscape.
- At water or land level: the Great Barrier Reef at eye level, as sky, water, and land emerging from water, and with a sense of a world beneath the water.
- Below water: the Great Barrier Reef as an underwater landscape. The three-dimensional qualities of the underwater landscape, its relative intimacy (with long-distance views rarely experienced), and the position of the viewer 'floating' above and within the landscape are all distinctive. The aesthetic experience is also enhanced because this perspective is not part of everyday human experience.[33]

For the early European visitors to the Reef, its natural beauty was appreciated at the water or land level, with an emphasis on the vistas of bays and islands and what could be seen through the water. An example is Matthew Flinders during his voyage on the *Investigator* in 1802. As an early European explorer, Flinders knew little of the Reef, other than its potential perils, and was focused on mapping its navigational hazards.[34] Nonetheless he was struck by its underwater beauty:

> *"We had wheat sheaves, mushrooms, stags horns, cabbage leaves and a variety of other forms, glowing under water with vivid tints of every shade betwixt green, purple, brown and white; equalling in beauty and excelling in grandeur the most favourite parterre [ornamental garden] of the curious florist."* [35]

Over the subsequent centuries, changes in how people access the Reef and developments in underwater technology (for example glass-bottomed boats, underwater observatories, snorkelling, scuba diving, underwater cameras) have changed the ways in which people experience the Reef and appreciate its aesthetic values (Figure 4.3). From images featuring land-based aesthetic experiences, the emphasis has shifted to include its underwater beauty. Being able to view the Reef from the air has also changed peoples' understanding of its size and beauty.

The Region continues to have great natural beauty; underwater aesthetic values have declined.

The Region's natural beauty is generally intact, especially for offshore coral reefs and aerial vistas, as well as for neighbouring islands (many of which are national parks). However, increasing human infrastructure along the coastline and on islands, and increased shipping traffic have affected some of the values that contribute to the Region's aesthetic values, for example its natural coastal vistas and tranquillity. In addition, marine debris has diminished aesthetics in some areas.[37] Water clarity is one of the Reef's features most valued by visitors.[37] It is affected by increased turbidity from sediment and nutrients from land-based run-off and the resuspension of dredge material. Declining coral cover in the southern two-thirds of the Region has reduced underwater aesthetic values.

Developments in underwater technology have made it easier to visit and appreciate the Reef environment © Chris Jones

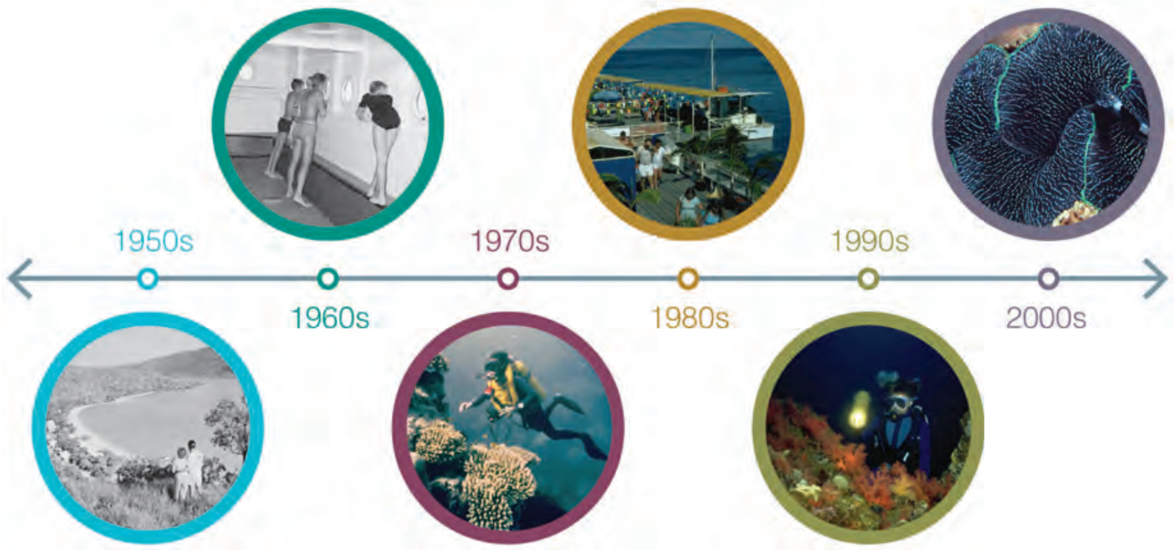


Figure 4.3 Changing experiences of aesthetic values
Over the decades, developments in technology have changed the ways people experience the Reef's natural beauty. Experiences based on panoramas of islands and beaches (such as that depicted in the left-hand image taken in the 1950s), have been augmented by those in glass-bottomed boats and observatories from the 1960s, and then by underwater experiences — most recently including opportunities for high quality close-up photography. Source: 1950s–1970s: National Archives of Australia[36], 1990s: Ken Anthony

4.4.3 Scientific heritage values

The Reef has been an area of scientific exploration, discovery and monitoring since the voyage of the *Endeavour* in 1770 with Joseph Banks on board — the scientist credited with introducing the western world to eucalypts, acacias and banksias (the genus named after him). Subsequently, naturalists and geologists on European voyages through the Reef plus amateur naturalists collected, recorded, reported and interpreted the natural environments of the Reef.[38] The work of these observers and collectors contributed to early scientific understanding of coral reef ecosystems and their geological origins. Examples include Joseph Jukes on the *Fly* during its survey of the Great Barrier Reef from 1842 to 1845. On islands such as Lady Musgrave and Lizard and reefs throughout the Region, Jukes closely studied and described the structure and biodiversity of coral reefs, wondering at their complexity and origins.

Later in the century, fisheries scientist William Saville-Kent became a key figure in early Reef science. With the starting point of the commercial potential of the Reef, he collected and recorded hundreds of Reef species and advocated for teaching marine biology and establishing research stations.[39] Also important to scientific understanding of the Reef was the Great Barrier Reef Expedition to Low Isles in 1928–29 when a party of scientists led by C.M. Yonge conducted a 10-month investigation of the Reef environment — the first detailed scientific study of the Reef covering geography, biology, geology and coral taxonomy.[40]

Since these early scientific undertakings, the scientific significance of the Reef's environment has increased through ongoing research in tropical marine ecosystems, development of a network of research stations along the Reef, creation of the Australian Institute of Marine Science and establishment of marine science programs at various universities.

Many ground-breaking scientific advances have happened in the Region. Examples include research about: mass coral spawning[41]; larval dispersion[42,43,44]; and water quality[45,46]. For coral research

Map of Low Isles by the Great Barrier Reef Expedition, 1928–29. Low Isles has historical scientific significance as the base for the Great Barrier Reef Expedition undertaken in 1928–29, the first detailed scientific study of the Reef environment.

Many ground-breaking scientific advances have happened in the Region.

alone, there have been about 3000 scientific journal articles relating to the Great Barrier Reef in the 10 years since 2004 which have been cited over 50,000 times.[47] Reef research has also contributed to protection and management of tropical marine systems throughout the world, including through improving understanding of the importance of marine protected areas.[48,49] The statement of outstanding universal value for the Great Barrier Reef World Heritage Area recognises its enormous scientific importance.[50]

The scientific value of monitoring activities undertaken over extended periods (such as those for marine turtles, dugongs, seabirds and corals) continues to increase as the timespan for each study grows.

The scientific heritage values of the Region are generally being maintained. Sites of significant historic scientific research and monitoring are known. The findings and the locations of the work undertaken are generally recorded in scientific publications and databases.

4.5 Current state and trends of world heritage and national heritage values

The Great Barrier Reef is listed on both the World Heritage List and the National Heritage List and therefore contains both world heritage values and national heritage values. The two categories of heritage values are combined in this assessment as the area's national heritage listing is based on its recognition as a world heritage property — meaning that its national heritage values correspond to its world heritage values.

The Great Barrier Reef World Heritage Area covers 348,000 square kilometres and includes both marine areas and all the Great Barrier Reef islands contained inside its boundary. The property has the same boundary as the Great Barrier Reef Region, except that it also includes the internal waters and islands of Queensland.

The Great Barrier Reef was inscribed on the World Heritage List in 1981 and on the National Heritage List in 2007. It was the first coral reef ecosystem in the world to be listed as world heritage and today is one of only 46 marine world heritage areas. Its world heritage listing recognised the area was of outstanding universal value.

> *'Outstanding universal value is defined as cultural and/or natural significance which is so exceptional as to transcend national boundaries and to be of common importance for present and future generations of all humanity.'*[51]

A property is considered to be of outstanding universal value if it meets one or more of 10 world heritage criteria and is inscribed on the World Heritage List.[51] In addition, to be deemed to be of outstanding universal value '*a property must also meet the conditions of integrity and/or authenticity and must have an adequate protection and management system to ensure its safeguarding*'.[51]

Recognition of the Great Barrier Reef's outstanding universal value was based on all the four natural world heritage criteria in place at the time of listing — acknowledging the Reef's natural values, together with the

The Great Barrier Reef has natural significance of common importance for all humanity © Matt Curnock strong ongoing links between Aboriginal and Torres Strait Islanders and their sea country.[52] The criteria have been amended and renumbered since the Reef was inscribed (Table 4.3).

Table 4.3 World heritage criteria relevant to the Great Barrier Reef
The world heritage criteria have been modified since listing of the Great Barrier Reef in 1981.

Short title	Current criteria	Criteria at time of listing
Natural beauty and natural phenomena	(vii) contain superlative natural phenomena or areas of exceptional natural beauty and aesthetic importance	(iii) unique, rare or superlative natural phenomena, formations or features or areas of exceptional natural beauty, such as superlative examples of the most important ecosystems to man
Major stages of the Earth's evolutionary history	(viii) be outstanding examples representing major stages of Earth's history, including the record of life, significant ongoing geological processes in the development of landforms, or significant geomorphic or physiographic features	(i) outstanding examples representing the major stages of the Earth's evolutionary history
Ecological and biological processes	(ix) be outstanding examples representing significant ongoing ecological and biological processes in the evolution and development of terrestrial, fresh water, coastal and marine ecosystems and communities of plants and animals	(ii) outstanding examples representing significant ongoing geological processes, biological evolution and man's interaction with his natural environment
Habitats for conservation of biodiversity	(x) contain the most important and significant natural habitats for *in situ* conservation of biological diversity, including those containing threatened species of outstanding universal value from the point of view of science or conservation	(iv) habitats where populations of rare or endangered species of plants and animals still survive

Only those attributes of the Region that are consistent with the four criteria for which the Great Barrier Reef was inscribed are its world heritage values. A *Statement of the outstanding universal value of the Great Barrier Reef World Heritage Area*[50] is the official statement adopted by the World Heritage Committee outlining how the property met the criteria for outstanding universal value, integrity and protection and management at the time of listing.

Given the broad scope of the criteria under which it was listed, almost all attributes of the Reef's environment are relevant to the criteria and contribute to its outstanding universal value (Appendix 3). This includes the Region's biodiversity, geomorphology, Traditional Owner connections to the area, its ecological processes, aesthetic values and natural phenomena. The notable exceptions are historic (for example, shipwrecks and lightstations), social and scientific heritage values which are not encompassed by the natural criteria.

In 2012 and 2013, the World Heritage Committee expressed concerns about the impact of development on the property's outstanding universal value and integrity. The Australian Government, as the responsible state party, is coordinating a range of actions to address these concerns. In particular, in 2013 the Australian and Queensland governments undertook a comprehensive strategic assessment of the property[53] and adjacent coastal zone[54], including an outline of proposed measures to strengthen protection and management arrangements.[55,56]

The following assessment of the world heritage values (and national heritage values) of the Region is based on the attributes identified in the statement of outstanding universal value. It draws on the evidence and assessments presented in this chapter and in the previous chapters on biodiversity (Chapter 2) and ecosystem health (Chapter 3).

4.5.1 Natural beauty and natural phenomena

The natural beauty of large areas of the property remains spectacular, especially for northern and offshore coral reefs and aerial vistas, as well as for neighbouring islands (many of which are national parks). The Reef remains visible from space and technological advances make these images more detailed and more accessible to the community.

Since 1986 — five years after world heritage listing — hard coral cover averaged over the entire Region has declined, principally in the southern two-thirds of the Region.[57] This has reduced underwater aesthetic value, as has increasing turbidity in inshore areas. The natural beauty of the property is also being affected by the presence of marine debris, especially on beaches.[37,58] Increasing infrastructure along the coastline and on islands, and increased shipping traffic have degraded some of the attributes identified as contributing to top-rating views.[59]

The Region retains its spectacular natural beauty; aesthetic values are diminished in some areas.

The scenic beauty of the Reef's islands is part of the property's natural beauty. While the majority of the Whitsunday Islands are protected and managed as national parks, there have been some changes to island scenery, such as on resort islands. Hinchinbrook Island is protected and managed as a national park and retains its spectacular natural scenery.

Many natural phenomena remain intact; declines in species have affected some.

While many of the natural phenomena identified in the statement of outstanding universal value remain intact, others are likely to have deteriorated (see Chapter 2). Nesting numbers of at least two species of marine turtle have declined but are now recovering; there are signs of decline for nesting populations of some other marine turtle populations and some seabirds. There are anecdotal reports of severe declines in the number and condition of potato cod at the Cod Hole — a site famous for the species. In contrast, the number of migrating humpback whales is increasing. Protection of known fish spawning aggregations has improved, but most sites are unknown.

4.5.2 Major stages of the Earth's evolutionary history

The Great Barrier Reef is the world's largest coral reef ecosystem. While its overall condition has deteriorated, it remains an outstanding example of an ecosystem that has evolved over millennia. It represents the major stages in the Earth's history, the record of life, geological processes in the development of landforms, and geomorphic and physiographic features.[60]

The Region remains an outstanding example of evolutionary history.

Coral reefs are one of the Region's key geomorphological features and it contains examples of all stages of reef development. The diversity of reef shape and size, for example fringing, shelf, ribbon and deltaic reefs (Figure 4.4), can be a function of substrate size, depth and, to a lesser extent, relative sea level history and carbonate productivity.[61,62] Submerged reefs are important recorders of sea-level change[63], the Earth's evolutionary history[63] and environmental change[64]. Some corals are showing signs of decreased calcification rates, which has long-term implications for their future as geomorphological structures.[65]

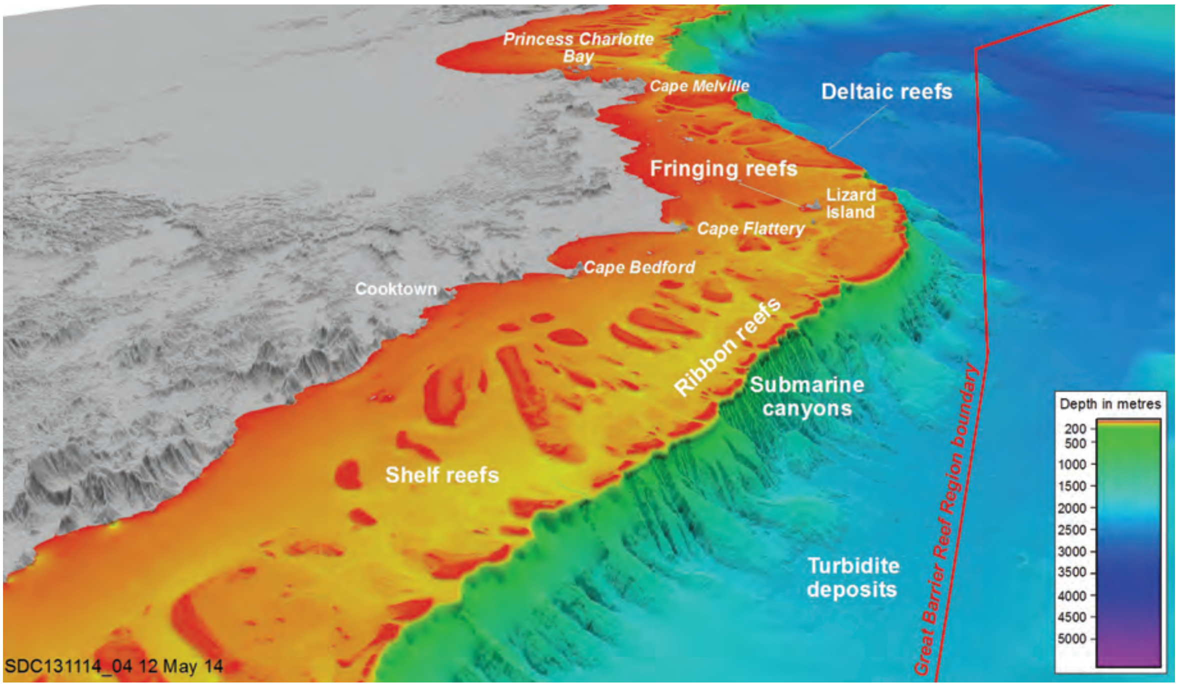
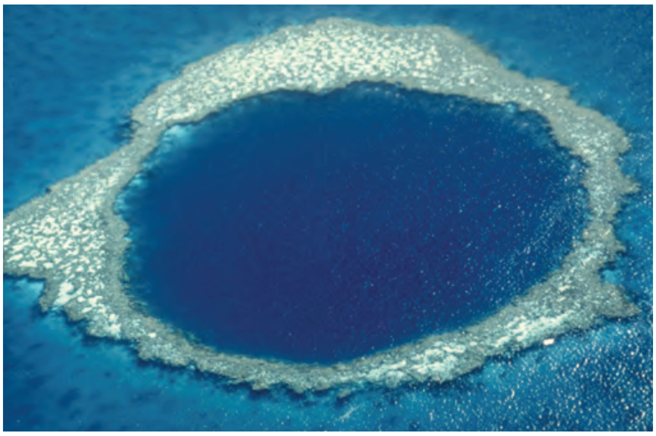


Figure 4.4 Geomorphological features
The area adjacent to Cooktown and Princess Charlotte Bay contains many of the Region's geomorphological features. These occur on the continental shelf, down the shelf edge and in the deeper water beyond. Image courtesy of Dr Robin Beaman, www.deepreef.org

Other geomorphological features in the Region that represent major stages of the Earth's evolutionary history include:

Palaeochannels — past river channels that have been filled in over hundreds of thousands of years by sediment and later inundated by sea level rise. They comprise channel depressions and the associated sedimentary processes of erosion and deposition. They are now an element of groundwater flows from the Region's catchment.[66]

Karstic features — landforms shaped by the dissolution of layers of soluble bedrock, such as limestone. In the Region, there are karstic channels on reefs that have been exposed during geological



The Blue Hole at Cockatoo Reef in the Pompey Complex, east of Mackay

periods of low sea level.[61,67] In addition, 'blue holes' — deep circular depressions with steep sides — are a rare karstic landform in the Region.[68]

Submarine canyons — occur along the shelf edge (Figure 4.4) and can modify oceanography to produce upwellings.[69] They also preserve information about sea level change, and sediment and tectonic movements.[70,71,72]

Turbidite deposits — at the base of the continental shelf (Figure 4.4). They are the result of sediment transport from the continental shelf and are responsible for distributing vast amounts of sediment into the deep ocean. They provide historical records about sedimentation in the adjacent shelf area, tectonic movements and responses to sea level change.[73]

Almost all geomorphological processes remain intact. Examples of all stages of reef development remain although the overall health of reefs, especially in the southern two-thirds of the property, has declined. Although little is known about geomorphological features such as palaeochannels, karstic features, submarine canyons and turbidite deposits, their depth and distance from shore mean they are likely to be rarely affected by direct use or flow-on effects from the catchment.

4.5.3 Ecological and biological processes

Most geomorphic, physical, chemical and ecological processes remain in good condition but some are deteriorating, especially in the inshore southern two-thirds of the Region. Processes associated with groups of species in decline (for example, corals and seagrasses) have likely also declined. Particularly in the inshore southern two-thirds, processes such as connectivity, nutrient cycling and sedimentation have deteriorated, principally associated with adjacent land-based activities. There is increasing evidence of intensified flow and accelerated warming in the East Australian Current.[74]

Some ecosystem processes such as sedimentation, nutrient cycling and recruitment are declining.

The diversity of the Reef ecosystem reflects the maturity of an ecosystem that has evolved over millennia.[75] The Region's species diversity remains high, but some species are in poor condition, especially inshore in the southern two-thirds of the Region.

Birds continue to play a role in seed dispersal and plant colonisation on cays and continental islands.[76,77] Introduced weeds have affected the native vegetation on a number of islands within the Region.[78]

Halimeda banks are an example of active calcification and accretion over thousands of years. They are poorly studied, but are likely to be in very good condition given their isolation from land-based impacts and their level of zoning protection from trawling.

The strong ongoing links between Aboriginal and Torres Strait Islanders and their sea country are recognised in the description of the property's outstanding universal value.[50] Traditional Owners with connections to the Great Barrier Reef maintain links to their sea country in the Region. Many Indigenous heritage values are under pressure, including sites of significance, stories, songlines, totems and structures (Section 4.2).

Traditional Owners with connections to the Great Barrier Reef maintain their ongoing links to sea country.

4.5.4 Habitats for conservation of biodiversity

The Great Barrier Reef remains a complex ecosystem, containing a rich mosaic of habitats. Some key habitats are under pressure, especially in the southern two-thirds of the Region where land-based run-off has affected inshore habitats and a combination of severe weather and outbreaks of crown-of-thorns starfish has affected coral cover[57] (see Chapter 2). There have been no records of species extinction, though the speartooth shark has not been recorded in or near the Region since 1983.

Habitat declines are affecting their ability to support dependent species, including those of conservation concern.

The Region's mangrove forests remain very diverse with at least 39 mangrove species and hybrids recorded.[76,79,80,81]

There have been significant declines in seagrass meadows in the southern two-thirds of the Region over the last five years, due especially to severe weather events and ongoing chronic impacts. This decline is reflected in an unprecedented number of stranded dugongs reported in the Great Barrier Reef, especially in 2011. Of the habitats that support marine turtles, the condition of seagrass meadows and coral reefs have declined significantly. While nesting habitats are generally in good condition, projected changes to environmental conditions such as sea level rise[82] and increasing air temperature[83] are predicted to affect them in the future.[84]

While the nesting habitats for seabirds remain in generally good condition, declines have been recorded for some seabird populations, in part related to declines in vegetation in nesting areas (for example on Gannet Cay) and food supplies to support reproduction (see Section 2.4.13).

Two inshore dolphin species are known to be at risk, including through deterioration of their habitats. The humpback whale population is recovering strongly after being decimated by commercial whaling.[85] Within the Region, their calving habitats are well protected.

Plant diversity is generally well protected, with about one-third of the islands contained within national parks.

4.5.5 Integrity

Integrity is an important prerequisite of outstanding universal value. At the time of inscription it was considered that to include virtually the entire Great Barrier Reef ecosystem within the property was a way of ensuring the integrity of the coral reefs in all their diversity.

Major impacts on the world heritage values arise from external pressures.

The property is of sufficient size to ensure the complete representation of the features and processes which convey its significance. It is vast, covering 14 degrees of latitude and extending 80 to 250 kilometres from the coast. Except for some small exclusions and about 600 of the 1050 islands, almost all of the World Heritage Area is within marine or national parks, and is therefore afforded a high level of protection and management. While some habitats, populations and processes are under pressure, the attributes of outstanding universal value remain largely intact overall. Factors external to the property — climate change, coastal development and land-based run-off — are affecting the ecosystem as are some impacts of direct use.

Activities within the property are comprehensively managed and direct use is generally sustainable; the remoteness of some of the property poses challenges for managing agencies.

4.5.6 Benchmarking outstanding universal value

The Reef continues to include all attributes necessary to express its outstanding universal value.

Many of the attributes identified in the official statement of outstanding universal value of the world heritage property (Appendix 3) remain in good or very good condition. Those related to coral reef and seagrass meadow habitats, marine turtles, seabirds and dugongs are assessed as being in poor condition overall, but areas of good condition are still present in the Region (Chapters 2 and 3). Attributes relevant to Traditional Owner's interaction with the environment are also assessed as being in generally poor condition (Section 4.2).

The condition of about two-thirds of the 38 attributes identified as contributing to outstanding universal value has been assessed as having deteriorated since 1981.[53] Examples include:

- superlative natural beauty above and below the water
- spectacular and globally important breeding colonies of seabirds and marine turtles
- ongoing ecological processes such as upwellings, larval dispersal and migration
- vegetation on cays and continental islands, exemplifying the important role of birds in seed dispersal and plant colonisation
- human interaction with the natural environment illustrated by the strong ongoing links between Aboriginal and Torres Strait Islanders and their sea country
- the world's most complex expanse of coral reefs
- large ecologically important interreefal areas and many seagrass species
- major feeding grounds for one of the world's largest populations of the threatened dugong.

The condition of many attributes has deteriorated since 1981.

Populations of humpback whales, estuarine crocodiles, loggerhead turtles and green turtles (southern stock) are recovering from historical declines.

With regard to the requirement for integrity, the area of the world heritage property has remained at about 348,000 square kilometres, recognising minor changes as a result of reclamation along the coast (approximately eight square kilometres). The property continues to include all attributes necessary to express its outstanding universal value. Since 1981, the system of protection and management for the property has improved substantially. While most of the island national parks in the area were declared by that time, only a small proportion of the area was declared as marine park. Only the Capricornia Section of the Great Barrier Reef Marine Park had been proclaimed by 1981, comprising about 3.4 per cent of what is now included in that marine protected area. The resources devoted to protection and management have also increased substantially since the property's listing. For example, in 1981 the budget of the Great Barrier Reef Marine Park Authority was $2.1 million and it had a staff of about 40 people.[52] Three decades later, with the Great Barrier Reef Marine Park fully declared and comprehensive management in place, its 2013–14 budget was over $50 million and it had about 220 employees. In addition, in 1981 there was no funding for direct day-to-day management[52], compared to about $17 million for the program in recent years.

4.6 Current state and trends of Commonwealth heritage values

The Commonwealth Heritage List is a list of natural, Indigenous and historic heritage places owned or controlled by the Australian Government. It includes places connected to defence, communications, customs and other government activities that reflect Australia's development as a nation. There are five places in the Region which are on the Commonwealth Heritage List and therefore have Commonwealth heritage values: Shoalwater Bay Military Training Area (part of the area, Figure 4.5); Low Island and Low Islets lightstation; Dent Island lightstation; North Reef lightstation and Lady Elliot Island lightstation. The lightstations are mapped in Figure 4.2.

Listing of a Commonwealth place is based on its heritage values being tested against nine criteria, seven of which are represented by the listed places in the Region (Table 4.4).[21]

Table 4.4 Commonwealth heritage values
The five Commonwealth heritage places in the Region are recognised under seven of the nine listing criteria.

Commonwealth Heritage List criteria	Shoalwater Bay Military Training Area	Low Island and Low Islets lightstation	Dent Island lightstation	North Reef lightstation	Lady Elliot Island lightstation
Processes: importance in the course, or pattern, of Australia's natural or cultural history	●	●	●	●	●
Rarity: possession of uncommon, rare or endangered aspects of Australia's natural or cultural history	●			●	●
Research: potential to yield information that will contribute to an understanding of Australia's natural or cultural history	●				
Characteristic values: importance in demonstrating the principal characteristics of a class of Australia's natural or cultural places or a class of Australia's natural or cultural environments			●		●
Aesthetic characteristics: importance in exhibiting particular aesthetic characteristics valued by a community or cultural group					●
Technical achievement: importance in demonstrating a high degree of creative or technical achievement at a particular period				●	●
Social value: strong or special association with a particular community or cultural group for social, cultural or spiritual reasons					
Significant person: special association with the life or works of a person, or group of persons, of importance in Australia's natural or cultural history					
Indigenous tradition: importance as part of Indigenous tradition		●			

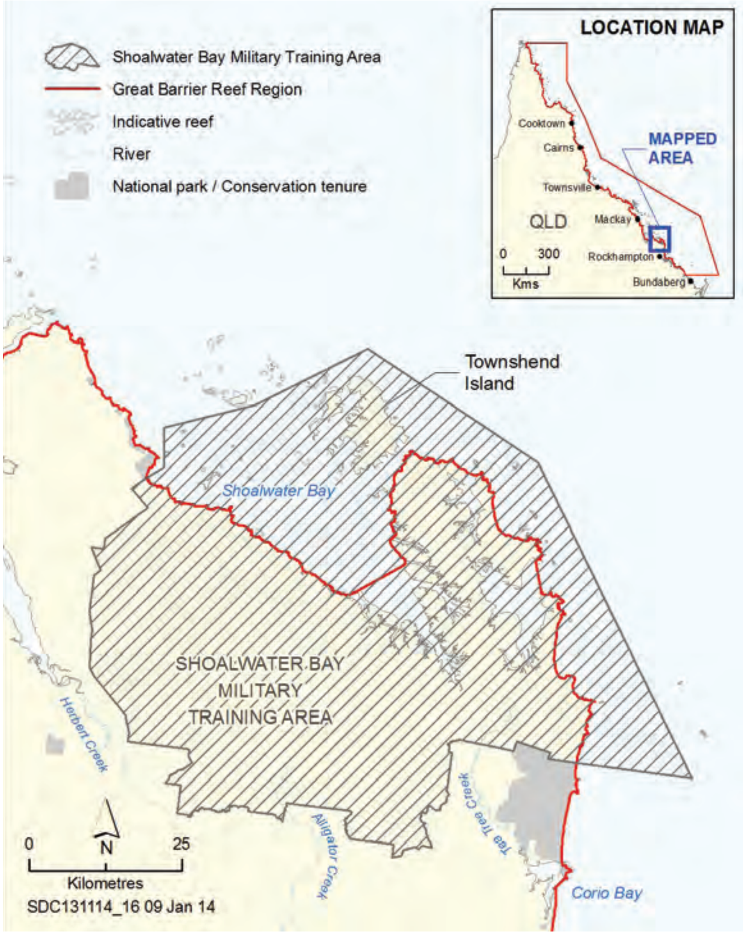


Figure 4.5 Shoalwater Bay Military Training Area Commonwealth heritage place
The Shoalwater Bay Military Training Area is a Commonwealth heritage place. Some of it is within the Region.

4.6.1 Shoalwater Bay Military Training Area

Shoalwater Bay Military Training Area (Figure 4.5) contains a range of coastal, sub-coastal and aquatic landscapes and ecosystems which occur in a relatively natural state with a high degree of integrity and diversity. It is of national importance to the maintenance and demonstration of geomorphological, ecological and biological processes of the coastal and hinterland environment.[21] The high integrity of much of the area, together with its steep environmental gradients, makes it a significant benchmark area for scientific research.[21] The area is one of the most important foraging areas in the southern part of the Region for threatened and vulnerable species, such as dugongs and green turtles.[21]

The area's very good condition can be attributed mainly to its restricted access as a defence training area. Military use of the site is strictly controlled, managed and monitored and has not caused any known changes to the ecological character of the site. The Department of Defence has pest animal management programs for the site and a regional oil spill response plan is in place.[86]

A 2009 state of the environment report for the area[86] concluded that the significant environmental and heritage values are in the same condition as when they were first recognised — in some cases, in better condition.

4.6.2 Lightstations and islands

Low Island and Low Islets lightstation The lightstation was constructed in 1878 and was the first in the north of the Reef. Its location inside the Great Barrier Reef was the first attempt to address the dangers to shipping approaching newly established ports, including Cairns and Port Douglas, from the north.[21] Low Island has heritage significance to Kuku Yalanji and Yirriganjdji Traditional Owner groups as part of their Dreamings. A heritage management plan for Low Isles and Low Islets lightstation is being developed.

Low Island retains its importance as part of the sea country of its Traditional Owners.

Dent Island lightstation was constructed in 1879. It is characteristic of a light tower built in response to the dramatic expansion of regular coastal shipping along the inner route of the Great Barrier Reef, following economic development in northern Queensland.[21] The lightstation is well maintained and a heritage management plan is in place.

North Reef lightstation was built in 1878. It is recognised for its rarity as one of the few lighthouses built on a coral reef, incorporating a residence at the base of the tower. The technical achievement of incorporating a rain water tank underneath the structure is also recognised.[21]

Lady Elliot Island lightstation demonstrates the historical development of a lightstation complex over time, with changes made in lighthouse technology and accommodation, and the addition of other service buildings. The lighthouse was built in 1873, using a timber-framed substructure and cast iron external cladding. The use of timber framing for the staircase is a rare example of this construction method in lighthouses in Australia.[21] The lightstation is also recognised for its aesthetic characteristics as a landmark feature which, along with the island, marks the southern end of the Great Barrier Reef Marine Park.[21] A heritage management plan is in place.

The lightstations with Commonwealth heritage values are generally well maintained.

For the heritage-listed lightstations and islands, their values are well recorded. There has been extensive maintenance in recent years which has substantially improved the condition of the structures.

4.7 Current state and trends of natural heritage values

The Region's natural heritage values are based on its biodiversity and its ecosystem processes (Chapters 2 and 3). The findings of these chapters demonstrate natural heritage values are generally in good condition, but some are in decline, especially in the inshore southern two-thirds of the Region.

4.8 Assessment summary — Heritage values

Section 116A(2)(a) of the *Great Barrier Reef Marine Park Regulations 1983* requires '*… an assessment of the current heritage values….*' of the Great Barrier Reef Region. This assessment is based on six assessment criteria:

- Indigenous heritage values
- historic heritage values
- other heritage values
- world heritage and national heritage values — the assessment of world heritage values and national heritage values are combined as the area's national heritage listing is based on its recognition as a world heritage property
- Commonwealth heritage values
- natural heritage values (assessed in Chapters 2 and 3).

4.8.1 Indigenous heritage values

Outlook Report 2009: Not assessed

2009 Grade	Current summary and assessment components	Assessment grade				Confidence
		Very good	Good	Poor	Very poor	Grade
Not assessed	**Indigenous heritage values:** Traditional Owners with connections to the Region maintain their cultural practices and customs. Places of Indigenous heritage values have not been systematically identified and many have deteriorated, especially around developed areas and on islands. Some species of cultural significance are under pressure. Story, language and songlines are being affected by activities in the Region.			■		
Not assessed	**Cultural practices, observances, customs and lore:** Traditional Owners are maintaining their cultural practices and transferring them to future generations.		■			◐
Not assessed	**Sacred sites, sites of particular significance, places important for cultural tradition:** Many sites of cultural significance are in good condition; others are under pressure, including from coastal development and severe weather.			■		◐
Not assessed	**Stories, songlines, totems and languages:** Some coastal activities and uses within the Region are affecting stories, songlines, totems and languages, especially in central and southern areas.			■		◐
Not assessed	**Indigenous structures, technology, tools and archaeology:** Indigenous structures, tools, technologies and archaeology have not been systematically identified and many are under pressure.			■		◐

Grading statements

■ **Very good**	■ **Good**	■ **Poor**	■ **Very poor**
Heritage values have been systematically and comprehensively identified and included in relevant inventories or reserves. Known heritage values are well maintained and retain a high degree of integrity.	Heritage values have been mostly identified and included in relevant inventories or reserves. Known heritage values are generally maintained and retain much of their integrity.	Heritage values have not been systematically identified. Known heritage values are degrading and generally lack integrity.	Heritage values have not been identified. Known heritage values are degraded and lack integrity.

Trend since 2009

New assessment for this report; no trend provided

Confidence

● Adequate high-quality evidence and high level of consensus
◐ Limited evidence or limited consensus
○ Inferred, very limited evidence

4.8.2 Historic heritage values

Outlook Report 2009: Not assessed

2009 Grade	Current summary and assessment components	Assessment grade				Confidence
		Very good	Good	Poor	Very poor	Grade
Not assessed	**Historic heritage values:** There is good understanding and recording of some aspects of historic heritage in the Region, for example known historic shipwrecks, a small number of World War II features and lightstations. Heritage values are being maintained or restored at heritage-listed lightstations. Most other places of historic significance are poorly recorded and their condition is not well understood.		■			
Not assessed	**Historic voyages and shipwrecks:** Many significant voyages of discovery sailed through the Region. Two historic shipwrecks are well documented. While hundreds have been mapped, many others remain to be located and assessed. There are no structured monitoring arrangements for any historic wrecks. Some have been affected by cyclones.			■		●

4.8.2 Historic heritage values *continued*

2009 Grade	Current summary and assessment components	Assessment grade				Confidence
		Very good	Good	Poor	Very poor	Grade
Not assessed	**Historic lightstations:** Heritage values are being maintained at heritage-listed lightstations, their values are well recorded and there has been extensive maintenance in recent years. Other historic lightstations in the Region that remain in service are well maintained.		■			●
Not assessed	**World War II features and sites:** While some World War II features and sites have been identified, most have not. Little is known of the condition of these features and sites. In addition to normal deterioration, some are being damaged by activities around the site. There is increasing awareness of these historic values.			■		●
Not assessed	**Other places of historic significance:** Other places of historic significance are poorly recorded and their condition is not well understood.			■		○

Grading statements				Trend since 2009
■ **Very good** Heritage values have been systematically and comprehensively identified and included in relevant inventories or reserves. Known heritage values are well maintained and retain a high degree of integrity.	■ **Good** Heritage values have been mostly identified and included in relevant inventories or reserves. Known heritage values are generally maintained and retain much of their integrity.	■ **Poor** Heritage values have not been systematically identified. Known heritage values are degrading and generally lack integrity.	■ **Very poor** Heritage values have not been identified. Known heritage values are degraded and lack integrity.	New assessment for this report; no trend provided **Confidence** ● Adequate high-quality evidence and high level of consensus ◐ Limited evidence or limited consensus ○ Inferred, very limited evidence

4.8.3 Other heritage values

Outlook Report 2009: Not assessed

2009 Grade	Current summary and assessment components	Assessment grade				Confidence
Not assessed	**Other heritage values:** The Region's social and scientific heritage is being maintained. The Great Barrier Reef continues to have great scientific significance. People continue to value and connect with its environment and its natural beauty is widely appreciated. Declines in environmental condition in the central and southern inshore areas have reduced underwater aesthetic values.		■			
		Very good	Good	Poor	Very poor	Grade
Not assessed	**Social heritage values:** Many aspects of the Region's natural and cultural environment have social significance, built around a history of personal experiences. Continued education and interpretation combined with ongoing use serve to maintain the Reef's social significance. The condition of some iconic sites has declined.		■			◐
Not assessed	**Aesthetic heritage values:** Most of the Reef's aesthetic values are derived from the natural environment. The Region generally continues to be an area of great natural beauty; however, coastal infrastructure, marine debris, reduced water clarity and declining coral cover, especially in southern and central inshore areas, have reduced underwater aesthetic values.		■			◐
Not assessed	**Scientific heritage values:** The long history of study of the Great Barrier Reef makes it of great scientific significance. Many ground-breaking scientific advances have happened in the Region. The findings and locations of scientific studies are generally well recorded. The significance of long-term studies continues to increase.		■			●

Grading statements				Trend since 2009
■ **Very good** Heritage values have been systematically and comprehensively identified and included in relevant inventories or reserves. Known heritage values are well maintained and retain a high degree of integrity.	■ **Good** Heritage values have been mostly identified and included in relevant inventories or reserves. Known heritage values are generally maintained and retain much of their integrity.	■ **Poor** Heritage values have not been systematically identified. Known heritage values are degrading and generally lack integrity.	■ **Very poor** Heritage values have not been identified. Known heritage values are degraded and lack integrity.	New assessment for this report; no trend provided **Confidence** ● Adequate high-quality evidence and high level of consensus ◐ Limited evidence or limited consensus ○ Inferred, very limited evidence

4.8.4 World heritage values and national heritage values

Outlook Report 2009: Not assessed

2009 Grade	Current summary and assessment components	Assessment grade				Confidence
		Very good	Good	Poor	Very poor	Grade
Not assessed	**World heritage values and national heritage values:** The outstanding universal value of the world heritage property remains in good condition, however the overall condition of some key attributes is poor and many have deteriorated since the property's listing in 1981. Those related to coral reef and seagrass meadow habitats, marine turtles, seabirds and dugongs are assessed as being in poor condition overall. The Region remains a globally outstanding example of an ecosystem that has evolved over the millennia. The natural beauty of most of the Region remains, however its underwater aesthetic value has declined in central and southern inshore areas. External pressures are affecting the property's integrity.		■			
Not assessed	**Natural beauty and natural phenomena:** The Region retains its spectacular natural beauty; aesthetic values are diminished in some areas. Many natural phenomena remain intact; declines in species have affected some phenomena.		■			●
Not assessed	**Major stages of the Earth's evolutionary history:** The Region remains an outstanding example of evolutionary history; coral reef health has declined in some areas.	■				◐
Not assessed	**Ecological and biological processes:** Many ecosystem processes remain in good condition; some, such as sedimentation, nutrient cycling and recruitment have deteriorated. Traditional Owners with connections to the Great Barrier Reef maintain their ongoing links to sea country.		■			◐
Not assessed	**Habitats for conservation of biodiversity:** The Reef remains a mosaic of habitats; some are under pressure. Habitat declines, especially in central and southern inshore areas, are affecting their ability to support dependent species, including those of conservation concern.		■			◐
Not assessed	**Integrity:** The property is large enough to ensure the representation of its world heritage values. External factors are affecting the resilience of the ecosystem in some areas. The property is comprehensively managed.		■			◐

Grading statements

■ **Very good**	■ **Good**	■ **Poor**	■ **Very poor**
All elements necessary to maintain the outstanding universal value are essentially intact, and their overall condition is stable or improving. Available evidence indicates only minor, if any, disturbance to this element of outstanding universal value.	Some loss or alteration of the elements necessary to maintain the outstanding universal value has occurred, but their overall condition is not causing persistent or substantial effects on this element of outstanding universal value.	Loss or alteration of many elements necessary to maintain outstanding universal value has occurred, which is leading to a significant reduction in this element of the outstanding universal value.	Loss or alteration of most elements necessary to maintain the outstanding universal value has occurred, causing a major loss of the outstanding universal value.

Trend since 2009

New assessment for this report; no trend provided

Confidence

● Adequate high-quality evidence and high level of consensus

◐ Limited evidence or limited consensus

○ Inferred, very limited evidence

4.8.5 Commonwealth heritage values

Outlook Report 2009: Not assessed

2009 Grade	Current summary and assessment components	Assessment grade				Confidence
		Very good	Good	Poor	Very poor	Grade
Not assessed	**Commonwealth heritage values:** The five places in the Region that are included on the Commonwealth Heritage List retain the values for which they were listed. The Shoalwater Bay Military Training Area and the four historic lightstations have been well recorded, retain their integrity and are in good condition. Low Island retains its importance as part of Indigenous tradition.		■			
Not assessed	**Processes:** All five sites continue to demonstrate their importance in the course of Australia's history.		■			●
Not assessed	**Rarity:** The Shoalwater Bay Military Training Area continues to support vulnerable and endangered species. The rare attributes of Lady Elliot Island and North Reef lightstations remain.		■			●
Not assessed	**Research:** The Shoalwater Bay Military Training Area retains the values that make it a significant scientific benchmark area.		■			●

4.8.5 Commonwealth heritage values *continued*

2009 Grade	Current summary and assessment components	Assessment grade				Confidence
		Very good	Good	Poor	Very poor	Grade
Not assessed	**Characteristic value:** Dent Island and Lady Elliot Island lightstations continue to demonstrate the adaptation of lighthouse construction.		🟦			●
Not assessed	**Aesthetic characteristics:** Lady Elliot Island lightstation continues to be a landmark feature.		🟦			●
Not assessed	**Technical achievement:** The attributes of Lady Elliot Island and North Reef lightstations that demonstrate technical achievement remain.		🟦			●
Not assessed	**Indigenous tradition:** Low Island retains its importance as part of the sea country of its Traditional Owners.		🟦			●

Grading statements				Trend since 2009
🟦 **Very good** Heritage values have been systematically and comprehensively identified and included in relevant inventories or reserves. Known heritage values are well maintained and retain a high degree of integrity.	🟦 **Good** Heritage values have been mostly identified and included in relevant inventories or reserves. Known heritage values are generally maintained and retain much of their integrity.	🟩 **Poor** Heritage values have not been systematically identified. Known heritage values are degrading and generally lack integrity.	🟩 **Very poor** Heritage values have not been identified. Known heritage values are degraded and lack integrity.	New assessment for this report; no trend provided **Confidence** ● Adequate high-quality evidence and high level of consensus ◐ Limited evidence or limited consensus ○ Inferred, very limited evidence

4.8.6 Natural heritage values

Outlook Report 2009: Not assessed

2009 Grade	Current summary	Assessment grade			
		Very good	Good	Poor	Very poor
Not assessed	**Natural heritage values:** Most of the Region's natural heritage values remain in good condition, but some are in decline, especially in its southern two-thirds. Values in poor condition include coral reefs and corals, seagrasses, seabirds, sedimentation, nutrient cycling and sea temperature. Populations of some iconic species such as dugongs and marine turtles are also in poor condition.		🟦		

Grading statements				Trend since 2009
🟦 **Very good** Heritage values have been systematically and comprehensively identified and included in relevant inventories or reserves. Known heritage values are well maintained and retain a high degree of integrity.	🟦 **Good** Heritage values have been mostly identified and included in relevant inventories or reserves. Known heritage values are generally maintained and retain much of their integrity.	🟩 **Poor** Heritage values have not been systematically identified. Known heritage values are degrading and generally lack integrity.	🟩 **Very poor** Heritage values have not been identified. Known heritage values are degraded and lack integrity.	New assessment for this report; no trend provided

Children playing at Starcke River

4.8.7 Overall summary of heritage values

An assessment of heritage values of the Region was introduced as a legislative requirement for the Great Barrier Reef Outlook Report in late 2013. It reflects the 2008 amendment of the main object of the *Great Barrier Reef Marine Park Act 1975* to include protection and conservation of the heritage values.

Traditional Owners with connections to the Region maintain their cultural practices and customs. For them, nature and culture combine to make a living heritage, with the natural environment fundamental to their culture and their connections to land and sea country. As a result, impacts on natural heritage values also affect Indigenous heritage values. Other factors are also placing these values under pressure, for example coastal development activities and uses within the Region.

The aesthetic heritage values of the Region are also closely linked to its natural attributes, such as coral reefs, islands, water clarity and calmness, and marine animals. While the Region generally continues to be an area of great natural beauty, declines in the natural environment, especially in inshore areas of its southern two-thirds, have reduced underwater aesthetic values.

The Great Barrier Reef has been a feature of Australia's history since Lieutenant James Cook's exploration of its 'coral labyrinth' in the late eighteenth century. This continuing history of discovery, appreciation and use has resulted in places of historic significance, such as lighthouses and shipwrecks. It has also built the social significance of the Reef. Most historic heritage values are generally in good condition, although many potential historic heritage values are yet to be located and recorded. Ongoing global interest in the Reef, combined with its use by generations of people, serves to preserve and enhance the social significance of the Region's environment.

There is also a long history of scientific studies in the Region. From early natural history observations to present-day research, findings from the Region have helped inform global understanding of tropical marine ecosystems.

Commonwealth heritage-listed places in the Region retain the values for which they were listed. They are well recorded, retain their integrity and are in good condition. Natural heritage values close to the populated coast are more likely to have declined due to more intensive human activity in the adjacent catchment. Those that are more remote and occurring at greater depths are more protected from impact.

Informed by the assessments of biodiversity, ecosystem health and the range of heritage values in the Region, it is concluded that the outstanding universal value of the world heritage property remains in good condition, however the overall condition of some key attributes is poor and many attributes have deteriorated since the property's listing in 1981. This has affected some aspects of the Region's natural beauty and natural phenomena, ecological and biological processes, and habitats for the conservation of biodiversity. Traditional Owners with connections to the Great Barrier Reef maintain their ongoing links to sea country; however, other aspects of their interaction with the environment are under pressure. The Region remains an outstanding example of the Earth's evolutionary history.

An overarching theme of all aspects of the Region's heritage values is that they are poorly recorded and rarely monitored. This has contributed to the grades assigned to the condition of many values and directly affects the ability to protect and manage them.

The diversity of colours and shapes is recognised as one of the Reef's world heritage attributes

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Commercial and non-commercial use

CHAPTER 5

‘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*

2014 Summary of assessment

Economic and social benefits of use	Use of the Great Barrier Reef continues to contribute to local communities and the national economy. Its economic value has increased over the past five years as has the number of jobs it supports. The number of recreational visits appears to be increasing and declines in tourism visitor numbers until 2011 are now beginning to be reversed. Traditional use helps maintain Traditional Owner connections to their sea country. Some users financially contribute to management.	↔ Very good, Stable
Impact of use	The impacts of different uses of the Great Barrier Reef overlap and are concentrated inshore, particularly next to developed areas. Some uses have only minor and localised effects, for example defence activities, research and educational activities, and traditional use. Cumulative effects of tourism and recreation activities are localised around popular locations. Port activities and their flow-on impacts are generally in areas that are already under pressure from an accumulation of impacts. There are concerns about overfishing of some fish stocks, and the effects of fishing on some species of conservation concern. The survival of non-retained species is not monitored or well understood.	↑ High impact, Increased

Full assessment summary: see Section 5.10

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Commercial and non-commercial use

5.1 Background

Outlook Report 2009: 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.

For thousands of years the Great Barrier Reef Region (the Region) has been an important resource and valued sea country for Traditional Owners. Since European settlement, 160 years ago, the Reef and its resources have been used and enjoyed by a variety of non-commercial and commercial uses, forming an important part of the social and economic fabric of regional Queensland, the Australian community, and the broader international community. A 2013 national survey estimated that 44 per cent of Australians had visited the Region in their lifetime.[1]

For almost 40 years, the Region has been managed as a multiple-use marine protected area, providing for protection, allowing for ecologically sustainable use, promoting understanding and enjoyment, and encouraging engagement. In managing the Region, environmental, economic and social aspects are considered in order to achieve the best outcomes for both the Great Barrier Reef and the community.

The Region supports significant commercial and non-commercial uses, especially commercial marine tourism and fishing (Figure 5.1). It is estimated that, in 2011–12, the Great Barrier Reef contributed approximately $5.6 billion to the Australian economy (Table 5.1) and supported employment equivalent to about 69,000 full-time positions.[2] This is an increase of about $200 million and 14,000 positions since 2006–07.[2,3] These estimates, however, are likely to be only a portion of the total economic value of the Reef as most ecosystem services of the Reef have not yet been calculated.[4] At the same time, ports and shipping activity adjacent to and through the Region has continued to increase, providing a link in the production chain for many industries and services in regional Queensland.

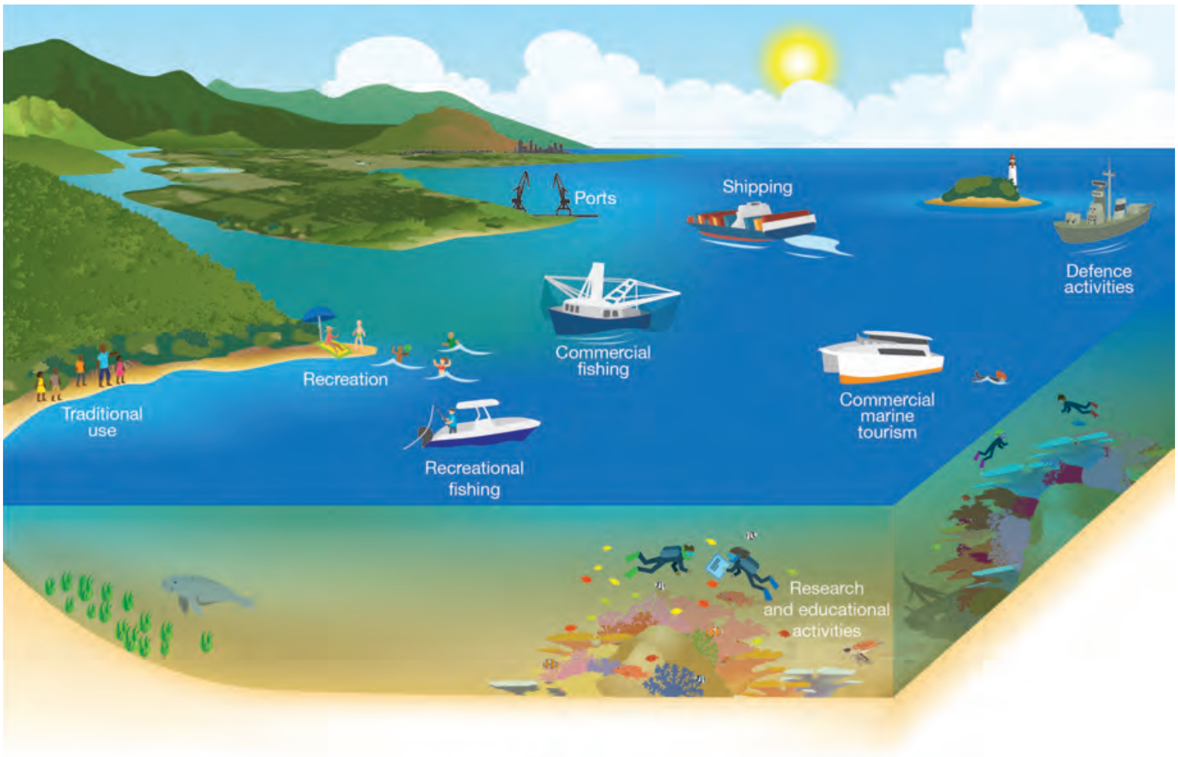

Figure 5.1 Commercial and non-commercial uses
There are a range of uses of the Region; some depend directly on the Reef's resources.

Table 5.1 Economic contributions of selected activities dependent on the Great Barrier Reef, 2006–07 and 2011–12
In 2011–12, Great Barrier Reef industries directly and indirectly contributed an estimated $5.6 billion to the Australian economy. This is an increase of approximately $200 million since 2006–07, but likely a small decrease in real terms. 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. Source: Access Economics 2008 and 2012[2,3]

Activity	2006–07 Value added ($million)	2011–12 Value added ($million)
Tourism	$5117	$5176
Commercial fishing	$139	$160
Recreational use (including fishing)	$153	$244
Total contribution	**$5409**	**$5580**

All of the Region's major uses are assessed.

This assessment of commercial and non-commercial use examines the current state and trends of the major uses of the Region and their associated benefits and impacts, with particular focus on changes since the *Great Barrier Reef Outlook Report 2009*[5]. The evidence provided in this assessment forms the basis for the assessment of direct use as a factor influencing the Region's values (see Section 6.6).

The uses assessed are:

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

Ports and shipping have been separated in this Outlook Report because of the differences in their likely impacts and management arrangements. Educational activities have been included with research to recognise use of the Region for primary, secondary and tertiary education.

Some of the activities assessed are directly dependent on the Region's natural resources (Reef-dependent) and others are carried out regardless of the natural environment (not Reef-dependent). Examples of Reef-dependent activities are traditional use of marine resources, commercial marine tourism, fishing, recreation, and research and educational activities. Reef-dependent activities are likely to be more sensitive to changes in the condition of the Region's values.[6] Examples of activities not dependent on the Reef include shipping, ports and defence activities.

Commercial and non-commercial uses occurring outside the Region that may indirectly affect its ecosystem and heritage values are considered in Chapter 6.

5.2 Commercial marine tourism

5.2.1 Current state and trends of commercial marine tourism

The long-term attractiveness of the Region as a tourism destination is largely based on the Great Barrier Reef's reputation as the world's largest and best known coral reef ecosystem — one that has spectacular and diverse species — combined with high standard tourism and protected area management. The Region's tourism industry is almost exclusively nature-based, with coral reefs and islands as the focus, and is reliant on an intact Great Barrier Reef ecosystem. There are opportunities to see iconic wildlife such as whales, marine turtles, sharks and seabirds and to go boating, diving, snorkelling, fishing, sailing, hiking, camping or to enjoy various water sports. Swimming, snorkelling, scuba diving and viewing animals are consistently popular tourist activities (Figure 5.2). The industry offers a wide range of tourism experiences, from cruise ships and live-aboard vessels to day trips on high speed catamarans, fishing charters and kayaking tours.

Commercial marine tourism continues to be a significant use of the Reef.

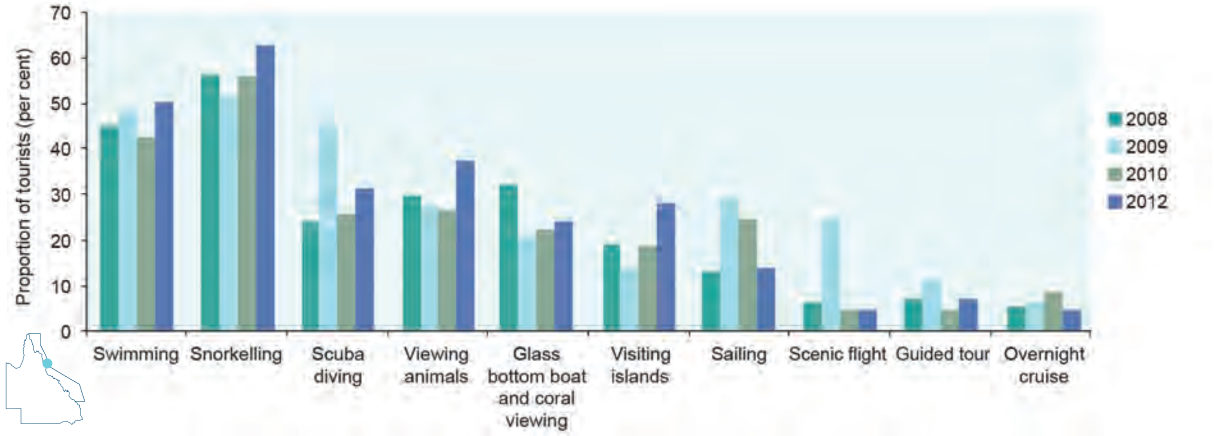

Figure 5.2 Reef activities undertaken by tourists departing Cairns, 2008–2012
Surveys of tourists departing from Cairns (a sample of 4337 people) showed swimming and snorkelling to be the most popular activities undertaken. No surveys were taken in 2011. Source: Prideaux et al. 2013[7]

Commercial marine tourism continues to be the most significant use of the Reef — both in terms of economic value and employment. Tourism activity in the Great Barrier Reef remains focused in a small portion of the Region with about 83 per cent of all tourism activity occurring in about seven per cent of the Region during 2013 (Figure 5.3). In that year, about 40 per cent of the full day visits took place in the Cairns Planning Area (offshore from Cairns and Port Douglas) compared with 44 per cent in 2008. For the Whitsunday Planning Area (the Whitsunday islands and adjacent reefs), there was the same proportion of the full day visits in 2013 compared with 2008 (43 per cent).

After a peak in 2004–05, visitor days to the Great Barrier Reef Marine Park declined by more than 16 per cent between 2005 and 2011 (Figure 5.4). The decline was attributable to a range of factors, including the high exchange rate of the Australian dollar, increased competition from international destinations, extreme weather events and the global financial crisis. Tourism is showing signs of a sustained recovery across the Marine Park and visitation in 2013 has increased by approximately 60,000 since 2012.[8] Visitation to the Cairns Planning Area is recovering strongly. Much of this result is attributable to attracting new Chinese tourists and the recovery of some traditional markets such as Japan. Visitation to the Whitsunday Planning Area and southern areas of the Region is also now recovering.

Reef visitation is recovering after many years of decline.

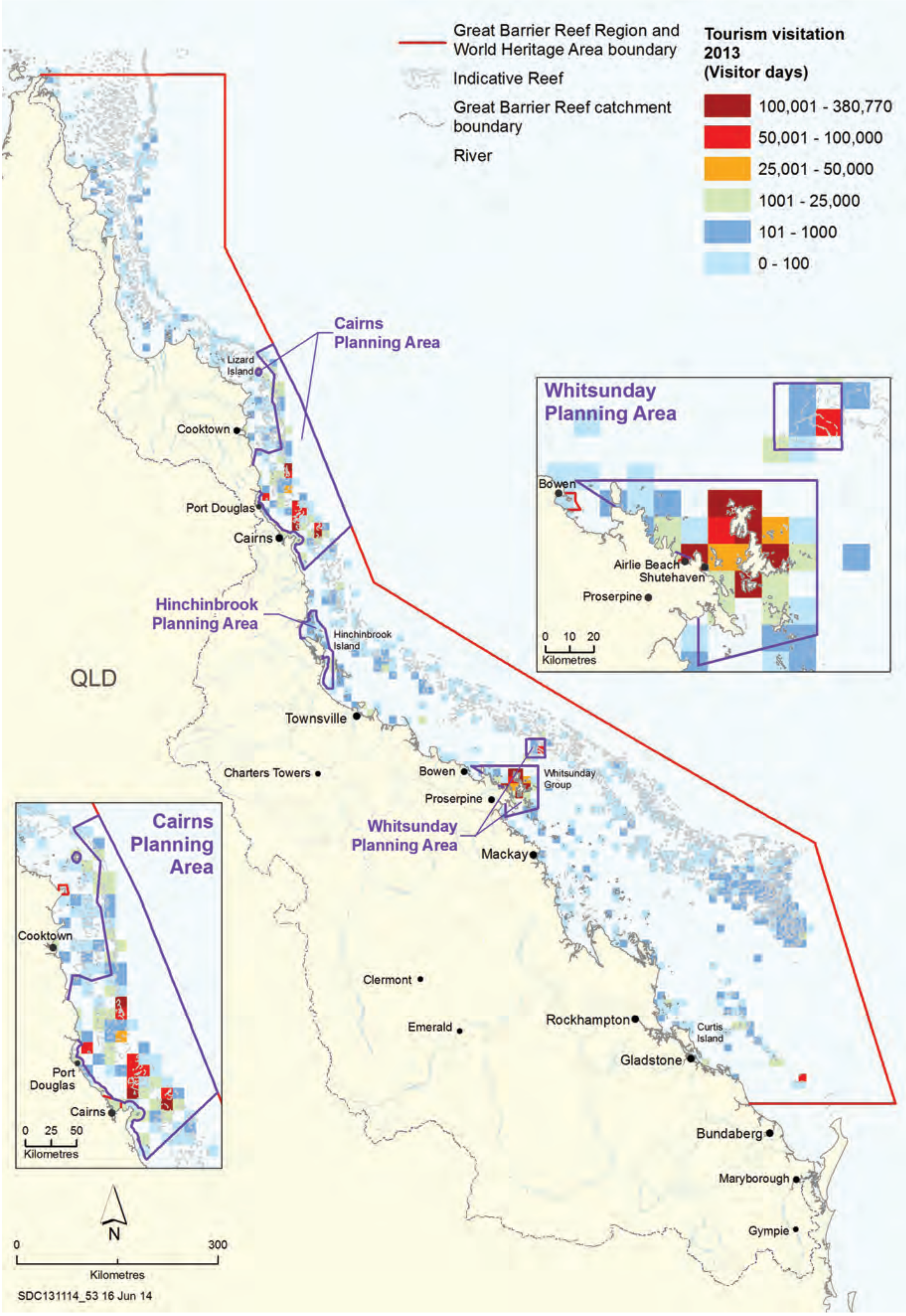

Figure 5.3 Distribution of tourism activity, 2013
Tourism use of the Great Barrier Reef Marine Park continues to be strongly focused on the areas offshore from Cairns and Port Douglas and around the Whitsunday islands and adjacent reefs.

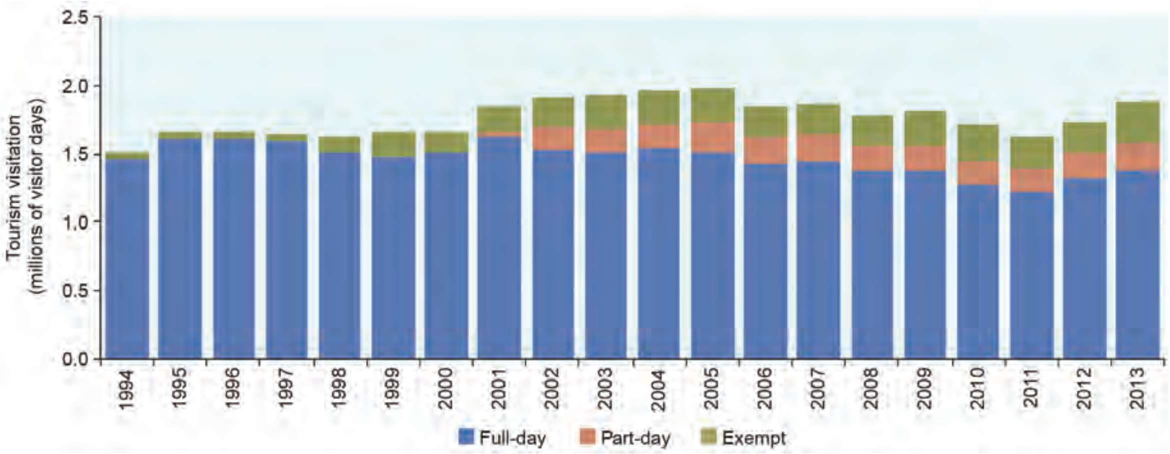

Figure 5.4 Number of tourism visitor days, 1994–2013
A 'visitor day' is a visit by one tourist for one day. For overnight visits, each day is counted separately (e.g. a three-day visit by a tourist to the Great Barrier Reef Marine Park represents three visitor days). A part-day visit refers to visitors who undertake a trip of less than three hours, and free of charge visitors include young children and trade familiarisations. Ongoing improvements in the way environmental management charge information is recorded have progressively allowed more accurate differentiation of visitation. This figure does not include stand-alone coral viewing activities and scenic flights, estimated at more than 0.2 million per year. It also does not include the estimated 2.3 million passenger transfers conducted each year through the Region to and from islands. Source: Great Barrier Reef Marine Park Authority 2013[9]

In 2013, a total of 1,887,317 visits were made to the Great Barrier Reef Marine Park by tourists on commercial tourism operations, of which 1,382,530 were full day visits and 195,249 were part-day visits or visitors who did not pay the full Environmental Management Charge.[9] While the overall number of visits has varied from year to year, the proportions between these three categories of visitation have remained relatively stable.

Commercial marine tourism presents the values of the Reef to millions of visitors.

In 2012, 66 per cent of tourism visitor days were carried by the 25 most active operators, 80 per cent were carried by 50 operators and 93 per cent by 100 operators. Many operations are small-scale and carry only small numbers of tourists (less than 10 people) or operate infrequently (less than 50 days per year).

Management The conduct of all tourism operations continues to be 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 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. In addition, a range of site management arrangements and specific policies, such as those addressing permit latency, apply to tourism operations.

As well as the mandatory management arrangements for commercial marine 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 managed by Ecotourism Australia. As part of its High Standard Tourism program, the Great Barrier Reef Marine Park Authority recognises certified operators through longer term permits, plus promotion on its website and at conferences and trade events.[10]

Tourism operators are active stewards of the Reef.

The number of Reef-based tourism operations that are certified as operating to high standards has increased from 44 in 2009 to 64 in 2013.[11] This has resulted in approximately 64 per cent of commercial tourists visiting the Great Barrier Reef with ECO Certified operators in 2013 (Figure 5.5).[9] While there is a small decrease (one per cent) in the proportion of tourists carried by ECO Certified operators between 2012 and 2013, the total number of tourists carried continues to increase.

Green Island and surrounding reef are a popular tourism destination © Matt Curnock

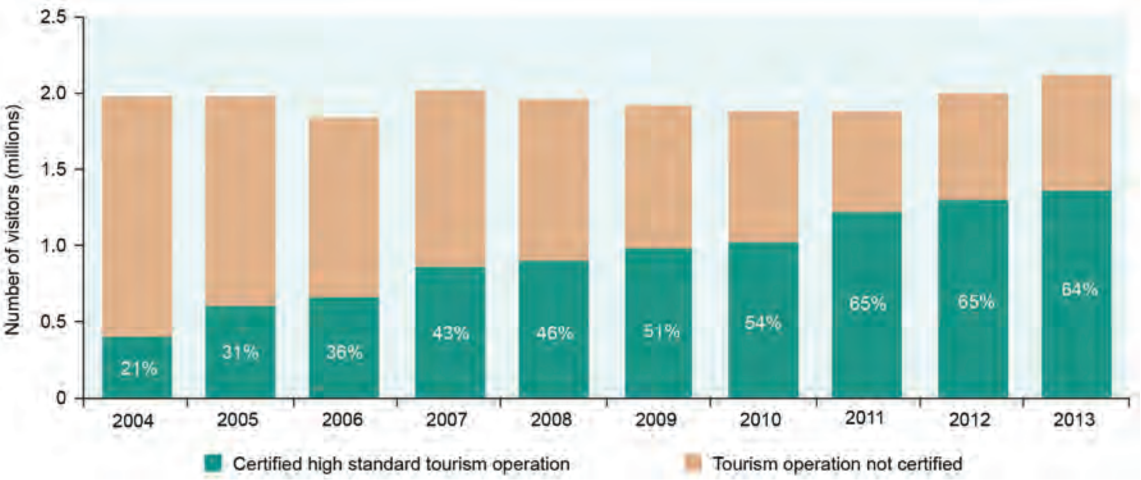

Figure 5.5 Percentage of visitors carried on high standard tourism operations, 2004–2013
Since the Great Barrier Reef Marine Park Authority's High Standard Tourism program began in 2004, the increasing number of certified high standard tourism operations has resulted in a higher number and proportion (percentage shown in the bars) of tourists using certified tourism products to visit the Reef. (Visitor numbers shown includes those undertaking coral viewing and scenic flights.) Source: Great Barrier Reef Marine Park Authority 2013[9]

As at 2013, 15 of the certified high standard operators are also certified by Ecotourism Australia through the Climate Action Certification program.[11] The program recognises tourism operators that operate to best practice and take initiatives to reduce greenhouse gas emissions.

The *Great Barrier Reef Tourism Climate Change Action Strategy 2009–2012* resulted in a range of products being developed to assist the tourism industry to reduce its climate footprint, including case studies, operator workshops, an online tourism operator's emissions calculator, climate incident response plans and climate action standards in both the Climate Action Certification and ECO Certification programs.

Marine tourism taking climate action

The island's lessee, Peter Gash, with a bank of solar panels

Lady Elliot Island Eco Resort is located on the southernmost reef island in the Great Barrier Reef. Operating an island resort 80 kilometres out to sea presents a multitude of daily challenges. The resort generates its own power, desalinates seawater for drinking, maintains a waste water treatment plant and recycles the majority of its rubbish. The resort has gained a wealth of knowledge about efficient technologies, sustainable island management and is a model for sustainable tourism on the Great Barrier Reef.

The resort is certified under both the ECO Certification and Climate Action Certification programs. It operates on a 'Four Es' philosophy — to look after our Environment we need to be Efficient, Economically sustainable and able to Educate effectively.

An energy audit of the resort's use of diesel generators and appliances was undertaken in 2005. By 2008, the generators had been replaced with a large hybrid solar power system. At the same time the resort's energy use was reduced by 32 per cent. By 2013, the resort's diesel consumption was almost 70 per cent lower.

5.2.2 Benefits of commercial marine tourism

Tourism in the Great Barrier Reef and its catchment represents about 90 per cent of the value-added economic contribution of Reef-dependent activities (Table 5.1).[2] In 2011–12, the industry made a contribution (directly and indirectly) of approximately $5.2 billion to the Australian economy and supported the equivalent of 64,338 full-time positions — making up 90 per cent of all full-time positions derived from the Great Barrier Reef.[2]

Although the Great Barrier Reef provides an impetus for travel to the broader catchment, not all visitors to the catchment visit the Reef. Analysis of more Reef-specific information indicates direct Reef-related expenditure in 2012 was about $480 million, which contributed almost $389 million (value-added) to Australia's economy and generated employment equivalent to more than 4800 full-time jobs. This is based on 1.9 million direct visits to the Great Barrier Reef Marine Park annually and excludes the 2.3 million passengers who transfer through it to adjacent islands.[2]

Importantly, the Reef is considered a major driver or incentive for international travellers to visit Australia.[7,12] Its biodiversity, aesthetic beauty, world heritage status, plus its scientific, educational and lifestyle values are strongly valued.[12]

A high proportion (84 per cent) of tourists surveyed in Cairns during 2012 reported that they had a 'good' experience at the Great Barrier Reef, 14 per cent reported that their experience was 'fair' and only 2 per cent rated their experience as 'poor'.[7] Tourist satisfaction is closely aligned to the attributes of their visit that are most important to them (Figure 5.6).[13]

The tourism industry is 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 $8 million each year from tourists on behalf of the Australian Government through the Environmental Management Charge (Figure 5.7). These funds directly contribute to management of the Great Barrier Reef.

Tourism operators have remained actively involved as stewards of the Reef over the past five years. Through the High Standard Tourism program and voluntary actions, operators are increasingly working to incorporate best practice standards into their activities. The Association of Marine Park Tourism Operators, in partnership with the Authority, is undertaking targeted control of crown-of-thorns starfish (see Section 7.3.12). Tourism operators also contribute to starfish reduction at individual sites through permitted culling activities. All these actions improve the sustainability of the industry and the health and resilience of the Reef.

Many operators continue to participate in research and monitoring programs, such as visitor surveys and the Eye on the Reef environmental monitoring program. Tourism operators have been engaged in the Eye on the Reef program since 1998 and, in 2013, 25 operators were involved in the Tourism Weekly monitoring program where crew monitor and report the environmental condition of reef sites they regularly visit. This monitoring now provides time series data focused in the areas offshore Cairns and Port Douglas and in the Whitsundays (Figure 5.8). Tourist operators also contribute to Reef Health and Impact Surveys, Sightings Network and the

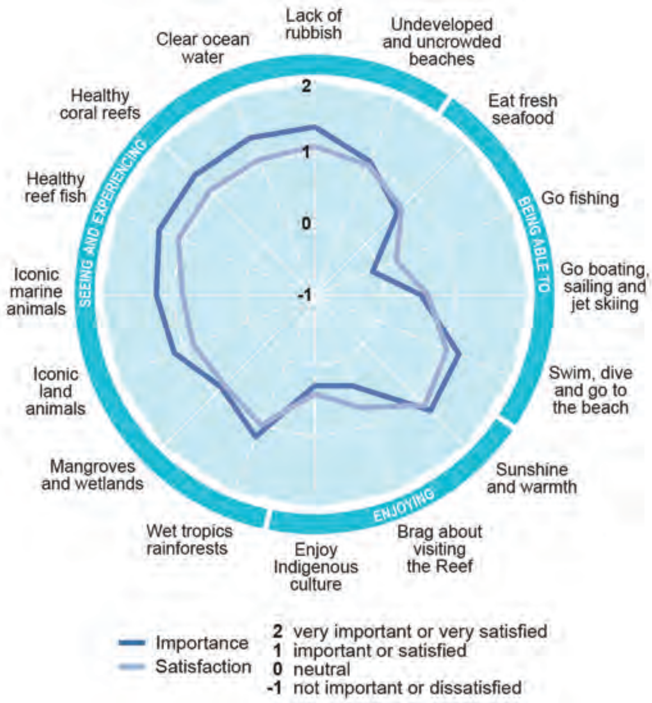

Figure 5.6 Importance and satisfaction scores for tourists, offshore Cairns, 2013
Tourists were surveyed to determine how important a range of factors were to them when deciding to come to the Cairns area, and how satisfied they were with those factors after their visit. The circle shows a rating for how important each factor was (the light blue line) compared to how satisfied visitors were with that factor during their visit (the dark blue line). Environmental factors shown on the left of the circle were identified as being most important. For those factors, mean satisfaction scores were consistently less than their importance scores. Source: Adapted from Stoeckl *et al.* 2013[13]

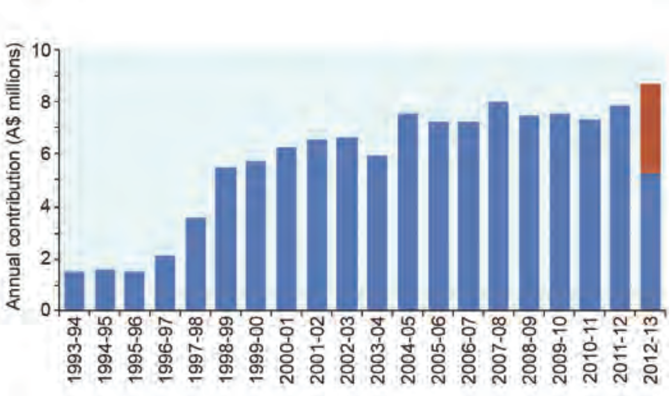

Figure 5.7 Financial contributions received from the Environmental Management Charge, 1993–94 to 2012–13
The tourism industry collects an Environmental Management Charge on behalf of the Australian Government from tourists to the Reef. These funds are vitally important in day-to-day management of the Great Barrier Reef Marine Park and in improving its long-term resilience. The value of the charge for a full day visitor has increased from $1.00 in 1994, to $2.00 in 1997, $4.00 in 1998, $4.50 in 2003, $5.00 in 2007, and $5.50 in 2010. It was temporarily reduced to $3.50 in 2012 for a period of three years, with the reduction in the charge being offset by the Australian Government (shown in red). Source: Great Barrier Reef Marine Park Authority 2013[9]

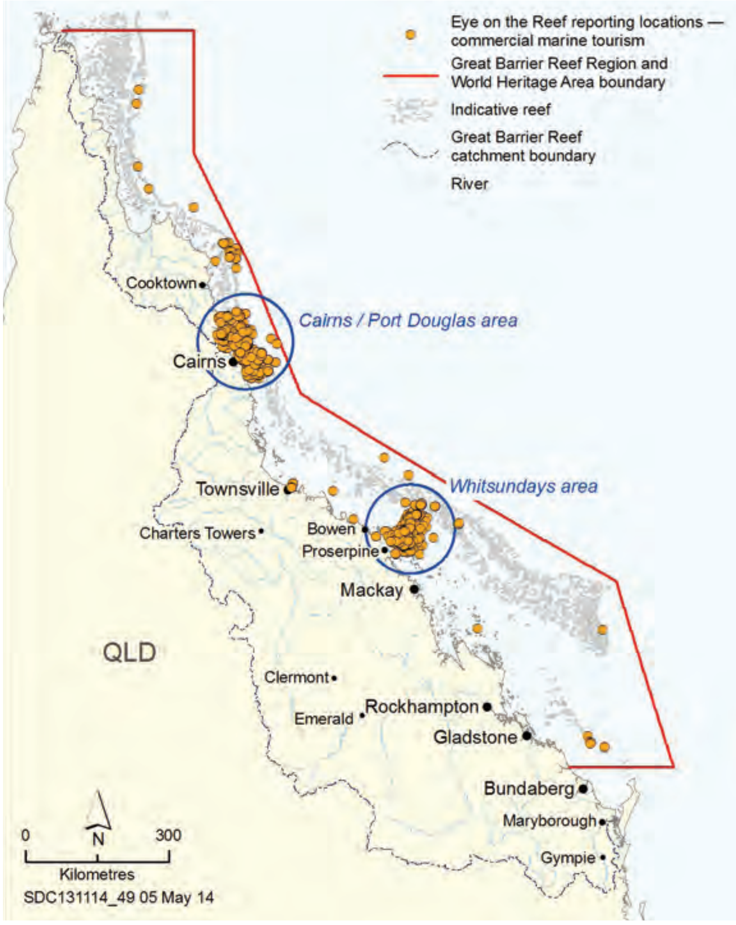

Figure 5.8 Location of Eye on the Reef weekly monitoring by tourism operators, 2011–2013

Monitoring of Reef condition by tourism operators through the Eye on the Reef program is focused in areas offshore Cairns and Port Douglas (22 operators), and in the Whitsundays (15 operators).

Rapid Monitoring survey program. Despite the financial pressures experienced through the downturn in tourism, tourism operators continued to actively gather reef health data through the different components of the Eye on the Reef program.

Importantly, the tourism industry continues to make much of the vast area of the Great Barrier Reef accessible to visitors. Without it, many visitors simply would not be able to enjoy or experience the Region's values. The industry, therefore, plays a key role in fulfilling Australia's world heritage obligation to 'present' the Great Barrier Reef World Heritage Area. Most tourism programs include education and interpretation activities, aimed at increasing appreciation and understanding of the natural environment and sustainable practices that support the Reef.

5.2.3 Impacts of commercial marine tourism

The Outlook Report 2009 highlighted that impacts caused by tourism are generally localised and have been largely reduced by regulation (for example, whale approach distances); site management arrangements (such as group size limits at locations, use of moorings, seasonal seabird closure areas); permit arrangements (for example, conditions to avoid and mitigate the impacts of structures and intensive activities, including fish feeding guidelines); education; and the adoption of best practices for activities (such as diving and snorkelling). While this assessment remains current for most aspects of commercial tourism use, there are some emerging areas and some not previously identified.

Reduced profitability across the industry has increased the potential risks associated with maintaining tourism-related structures in the Region (such as pontoons, jetties, underwater observatories and moorings). As structures age, they require more investment in maintenance to ensure they are not a threat to the surrounding environment, safe during cyclones and do not affect the amenity and presentation values of a location.

Coastal development, marinas and ancillary services associated with commercial marine tourism can cause consequential impacts on the environment within the Region, including contributions to dredging and disposal of dredge material, clearing or modifying coastal habitats and decreased water quality.

Tourism use of the Region has the potential to affect or displace other users, such as commercial fishers, Traditional Owners and recreational users, particularly in high use areas. There have been some recent examples of incompatibility between the activities of tourism operations and those of Traditional Owners exercising their traditional hunting rights.[14] There are also potential conflicts between sectors within the industry, such as charter fishers and site-based dive tourism. Into the future, an increasing number of tourists may affect visitor satisfaction, for example both tourists and local residents believe they would be much less satisfied with their experiences if there were twice as many tourists at their Reef destination.[13]

Tourism impacts are localised, mainly in a few intensively managed areas.

Discharge of sewage at sea (more than one nautical mile from any reef or island and the mainland) remains necessary for many tourism operations as there are insufficient land-based facilities to service the fleet's pump-out requirements.

Commercial marine tourism is not a main focus of compliance activities as offences by tourism operators are considered to be generally low impact to the ecosystem. However, a number of compliance incidents involving the tourism industry are reported annually, particularly from the more intensively used Cairns and Whitsunday areas. Examples include: breaches of marine parks permits; unpermitted activity; plan of management offences (such as undertaking activities not in accordance with group and vessel size limits); and moorings offences.

5.3 Defence activities

5.3.1 Current state and trends of defence activities

The Australian Defence Force has operated and trained in the Great Barrier Reef Region for more than 100 years. Operational defence activities in the Region include ocean surveillance, maritime search and rescue missions, and hydrographic survey and charting. Defence forces also provide critical support for border protection activities such as environment and fisheries protection, immigration controls, and biosecurity. Australian Navy, Army and Air Force bases at Cairns and Townsville serve as the key platforms for defence operational activities in the Region.

Most defence activities occur within a limited area of the Region.

Training activities are regularly undertaken in designated areas of the Region, covering less than four per cent of the area (Figure 5.9). While most of the designated defence training areas within or adjacent to the Region are small, the Townsville Star and the Shoalwater Bay Defence Training Area near Rockhampton are some of Australia's largest.

The Region is predicted to increase in importance as a defence training area over the next 25 years.[15] Some recent trends in defence activities include enhancing its capabilities in amphibious landings and other ship-to-shore or coastal manoeuvres. In addition, a recent shift in global military focus by the United States of America to enhance its capabilities in the Asia–Pacific region will likely affect defence use of the Region.[16]

Management All defence operational training activities are managed directly by the Australian Department of Defence. It is responsible for the conduct of training activities by defence forces, including those visiting from overseas. Management of the environmental impacts of defence training within the Great Barrier Reef is undertaken by the Department of Defence in collaboration with the Great Barrier Reef Marine Park Authority, the Australian Department of the Environment and Queensland Government agencies.

Defence activities are allowed under the zoning plan, with prior notification of intended activities. The Department of Defence has an environmental management plan that includes objectives to implement best practice environmental management. A strategic environmental assessment for defence activities[15] is implemented through a management agreement between the Department of Defence and the Great Barrier Reef Marine Park Authority[17].

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 observers, who are able to collect data on marine wildlife sightings, as well as ensure activities are delayed if required.

Figure 5.9 Defence training sites
The Australian Defence Force has operated and trained in the Region for over 100 years. Training is undertaken within designated areas.

5.3.2 Benefits of defence activities

Defence activities in the Region continue to directly contribute to the training and operation of Australia's defence services. Operational activities can also help, directly and indirectly, to achieve management objectives for the Region including hydrographic surveys, and fisheries and border protection patrols. In addition, the acquisition of land and sea areas around Shoalwater Bay in 1965 has provided ecological benefits. That area continues to support high biodiversity, including internationally significant migratory species and wetlands, and has stunning landscape features.[18]

Exercises during Talisman Sabre 2013

Defence bases at Cairns and Townsville also continue to strongly support these regional economies. Little is known of the economic benefits of most defence training activities to the coastal communities adjacent to the Region. The Talisman Sabre 2013 exercise was estimated to contribute $4 million to the Rockhampton economy and $200,000 to the Townsville economy.[19] Periodic visits from the United States of America, New Zealand and Singapore naval ships to ports at Townsville and Cairns also generate short-term economic benefits.[20]

5.3.3 Impacts of defence activities

Defence activities continue to be well planned and well resourced, so incidents causing harm to the habitats and species of the Region are rare. Standard operating procedures and contingency plans cover all defence activities, and any incidents are promptly reported and closely investigated. For example in July 2013, two explosive and two inert practice bombs were jettisoned from a United States marines aircraft during a military exercise. The explosive ordnance were located, retrieved and disposed of within two months.[21]

The level of planning and resourcing mean defence incidents are rare.

However, by their nature, defence activities pose risks which must be continually monitored and managed. The Australian Defence Force employs stringent quarantine measures to reduce the risk of introducing marine pests.[22] Other local and regional scale impacts include: debris and residue from expendable stores; death, injury or disruption to marine life; exclusion of other users; discharge of sewage and other wastes; oil spills; and risks to other users and their property if they stray into defence training areas during exercises.

There are a range of legacy impacts associated with past defence activities. Most significant is the presence of large amounts of unexploded ordnance (such as shells, missiles and bombs) and chemical warfare agents that were deliberately dumped at sea at the end of World War II.[23,24]

While modern defence training activities are well managed and have negligible impacts on the Great Barrier Reef, the predicted intensification of defence activities in the Region coincides with a decline in the Region’s ecosystem health caused by a range of other pressures. The Australian Defence Force continues to work with management agencies to review the risks posed by defence activities in light of new information about the Region’s declining ecosystem resilience.

5.4 Fishing

At a state-wide scale, the Region represents an important resource for Queensland’s fisheries. The Great Barrier Reef supports a range of fishing activities targeting a variety of species including fishes, sharks, crabs and prawns. For the purposes of this report, the term ‘fishing’ includes recreational, charter and commercial fisheries, plus the Queensland shark control program. Fishing activities associated with traditional use are considered in Section 5.9.

5.4.1 Current state and trends of fishing

Recreational fishing Recreational fishing is one of the most popular activities on the Great Barrier Reef. There has been a steady increase in vessel registrations in the Region’s catchments over the past few decades (Section 5.6.1)[25], which may translate to increased recreational fishing effort. A 2013 survey found approximately 65 per cent of catchment residents who had recently visited the Region in a boat went fishing.[26] A 2010 state-wide survey estimated that 703,000 residents went fishing in the 12 months prior to June 2010, capturing approximately 13.3 million individual fish, including a diverse range of bony fishes and sharks, skates and rays.[27] Coral trout, redthroat emperor, tropical snapper, morwong and sweetlip were commonly caught.[27] The most common recreational fishing method (80 per cent) was line fishing (including the use of baited hooks and lures), followed by fishing with pots (13 per cent).[27] Together, fishing and collecting with cast nets, pumps and spades, diving using spears, and hand collection comprised only seven per cent of all fishing effort.[27] It is estimated that the recreational sector has more non-retained catch than that retained.[5]

Recreational fishing catch rates may be declining.

The 2010 survey indicated that people were catching fewer fish for a similar level of effort compared to a decade ago.[27] This may reflect lower abundances or reduced accessibility to some target species in the last decade.

The availability of larger, more affordable and more fuel efficient vessels, combined with improvements in safety, mean recreational fishers are likely to be fishing further from the mainland and in more isolated areas. Strong growth in regional communities (see Section 6.2) is likely to increase the number of recreational fishers.

Charter fishing The average annual retained catch for charter fishing was slightly lower in the period 2009 to 2012 (357 tonnes retained, 162 tonnes discarded) compared to the period 2005 to 2008 (413 tonnes retained, 241 tonnes discarded), and the number of charter fishing days recorded decreased by around 2200 days per year.[28]

Coral trout are commonly caught by recreational fishers

Shark control program Since 1962, the Queensland shark control program has been implemented to minimise the risk of a shark attack on bathers in popular swimming locations by employing a combination of nets and drumlines. At the time of the Outlook Report 2009 there was capacity for 10 nets (five in Cairns, five in Mackay) and 317 drumlines within the Great Barrier Reef World Heritage Area. Since then, five nets have been removed from Cairns and replaced with 14 drumlines. The five nets in Mackay remain. There are currently up to 191 drumlines deployed at any one time within the World Heritage Area. The total of drumlines and nets varies — for example one net at Mackay is withdrawn during the marine turtle nesting season and replaced with six additional drumlines.

The major commercial fisheries operating in the Region are trawl, net, line and pot.

Commercial fishing Of the major commercial fisheries in the Region, trawl, net, line and pot remain the largest. The spatial distributions of fishing effort for these fisheries in the Region are presented in Figure 5.10.

The retained commercial catch in the Region was about 7900 tonnes of fisheries product in 2012 (Table 5.2). These four fisheries together retained about 7300 tonnes in 2012, a decrease of about a thousand tonnes from 2007.[28] The coral and marine aquarium supply fishery catch has remained fairly stable since 2007 (Table 5.2).

Knowledge about bycatch and discards is poor.

There is concern about the amount of biomass discarded and returned to the sea globally.[29] Preliminary analysis for the Region presented in the Outlook Report 2009 suggested that the non-retained catch by commercial fisheries is likely to be very much higher than that retained, with the trawl fishery still responsible for most of the commercial non-retained catch.[5] However, with no contemporary data on most fisheries bycatch and discards, knowledge about the quantum of non-retained catch in the Great Barrier Reef has not improved and uncertainty remains high.

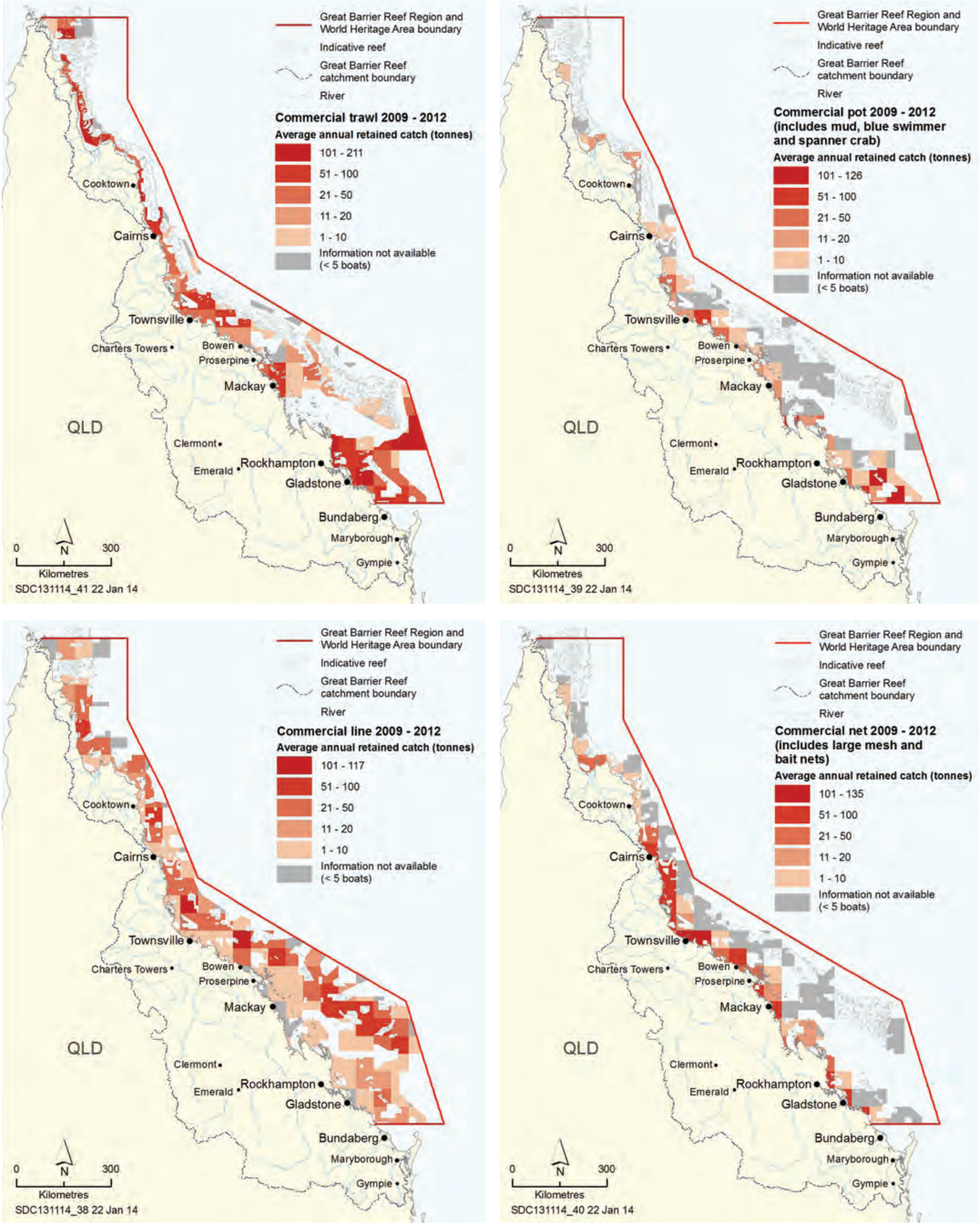

Figure 5.10 Spatial distribution of mean annual retained catch by commercial trawl, net, line and pot fisheries, 2009–2012
The amount of fisheries product taken from different areas in the Region varies for each of the major fisheries. Net and pot fisheries are primarily undertaken close to the coast, whereas line fishing and trawling extend further offshore and to the far north. The tonnages shown are for each fisheries 'grid' (a 30 nautical mile square), excluding the zones closed to fishing. Note: netting data displayed in the Conservation Park Zone include commercial bait netting (other netting is prohibited in this zone). Source: Department of Agriculture, Fisheries and Forestry (Qld) 2013[28]

Table 5.2 A comparison of commercial fisheries, 2007 and 2012

Source: Department of Agriculture, Fisheries and Forestry (Qld) 2013[28]

Type of fishery	Fishery	No. of primary fishing licences issued in Queensland 2012 (2007)	No. of active primary fishing licences operating in the Region 2012 (2007)	Estimated proportion (%) of Queensland catch occurring within the Region 2012 (2007)	Retained commercial catch in the Region 2012 (2007)	Main target species in the Region
Trawl	Otter trawl — on or near the seabed	438 (460)	179 (239)	52 (57)	3397 (3317) tonnes	Prawns, scallops, bugs, squids
	Beam trawl — on seabed	109 (unknown)	21 (25)	9 (7)	15 (28) tonnes	Prawns
Net (mainly large mesh nets)	East Coast Inshore Fin Fish (principally)	424 (500)	200 (227)	21 (28)	1429 (2016) tonnes	Barramundi, sharks, grey mackerel, threadfin salmons
Hook and line	Coral Reef Fin Fish, Spanish Mackerel and hook and line component of the East Coast Inshore Fin Fish (principally)	1285 (1531)	271 (280)	80 (69)	1734 (2115) tonnes	Coral trouts, cods, emperors, and tropical snappers, Spanish mackerel, other mackerels, barramundi, sharks, cobia
Pot	Mud crab, blue swimmer crab trap	430 (781)	179 (194)	30 (22)	559 (364) tonnes	Mud crab, blue swimmer crab
	Spanner crab trap	414 (507)	17 (24)	20 (34)	204 (525) tonnes	Spanner crab
Dive-based collection	Coral	59 (59)	31 (22)	75 (72)	89 (109) tonnes	'Live rock' and potentially hundreds of species
	Marine aquarium fish	45 (49)	28 (27)	50 (40)	~73,000 (~74,000) fish	Potentially hundreds of species — mostly damselfish, anemone fish, wrasses, angel fish
	Tropical rock lobster	28 (28)	8 (11)	99 (99)	142 (224) tonnes	Tropical rock lobster
	Trochus	6 (6)	1 (5)	100 (100)	16 (153) tonnes	Trochus
	Sea cucumber	18 (18)	5 (7)	99 (100)	376 (252) tonnes	White teatfish, blackfish, curryfish

In the sea cucumber fishery, there has been a shift to other species since the closure of the black teatfish fishery in 1999 and a reduction in catches of white teatfish. New species include the burying blackfish and the curryfish which together make up 80 per cent of the current total catch (Figure 5.11).[30] In 2004, rotational fishing was introduced to spread and limit the risk of over-exploitation of sea cucumbers.[31] This is designed to allow time to gauge fishing impact and for stock recovery between fishing pulses[30]. Recent management strategy evaluation for the sea cucumber fishery indicates that under the current management arrangements and catch levels, the overall risk of depletion for most reef-associated species under most scenarios was low. However, some current and past highly targeted species such as black teatfish and white teatfish show some risks under higher catch scenarios and should be managed with caution and more data gathered.

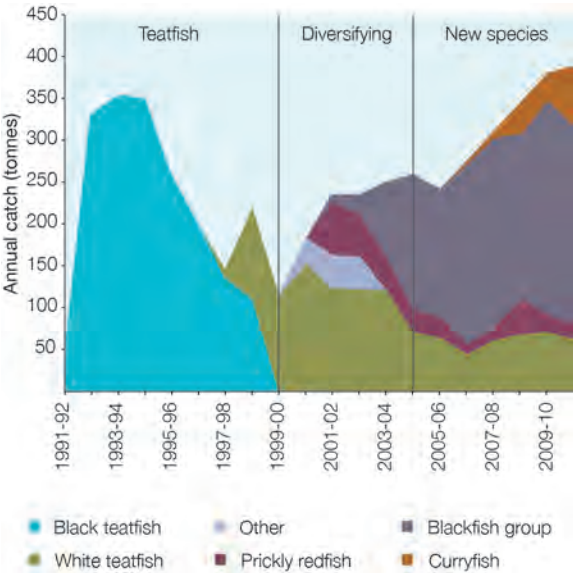

Figure 5.11 Catch of sea cucumbers, 1991–92 to 2010–11
Since the closure of the black teatfish fishery, a number of other sea cucumber species have been targeted in the fishery. The three phases of 'teatfish', 'diversifying' and 'new species' represent changes in the catch composition of the fishery. The blackfish group includes predominantly burying blackfish (Actinopyga spinea) and a small amount of blackfish (Actinopyga miliaris).
Source: Eriksson *et al.* 2013[30]

Several marine-based aquaculture operations (fishes, pearls and sponges) have been proposed or have begun in the Region over the past two decades but none are in operation at present, primarily due to economic or environmental sustainability issues. There are some land-based aquaculture operations in the adjacent catchment (see Section 6.4.1).

Catch and effort in the commercial trawl, net, line and pot fisheries have fluctuated over the last couple of decades (Figure 5.12), with annual catches and fishing effort lower in recent years compared to historical peaks. Factors influencing these patterns include abundance of resource species, management arrangements, weather events such as cyclones, market demands and other external factors (such as foreign exchange rates and fuel prices).

Catch in the main seafood fisheries fluctuates: it has generally been lower in recent years.

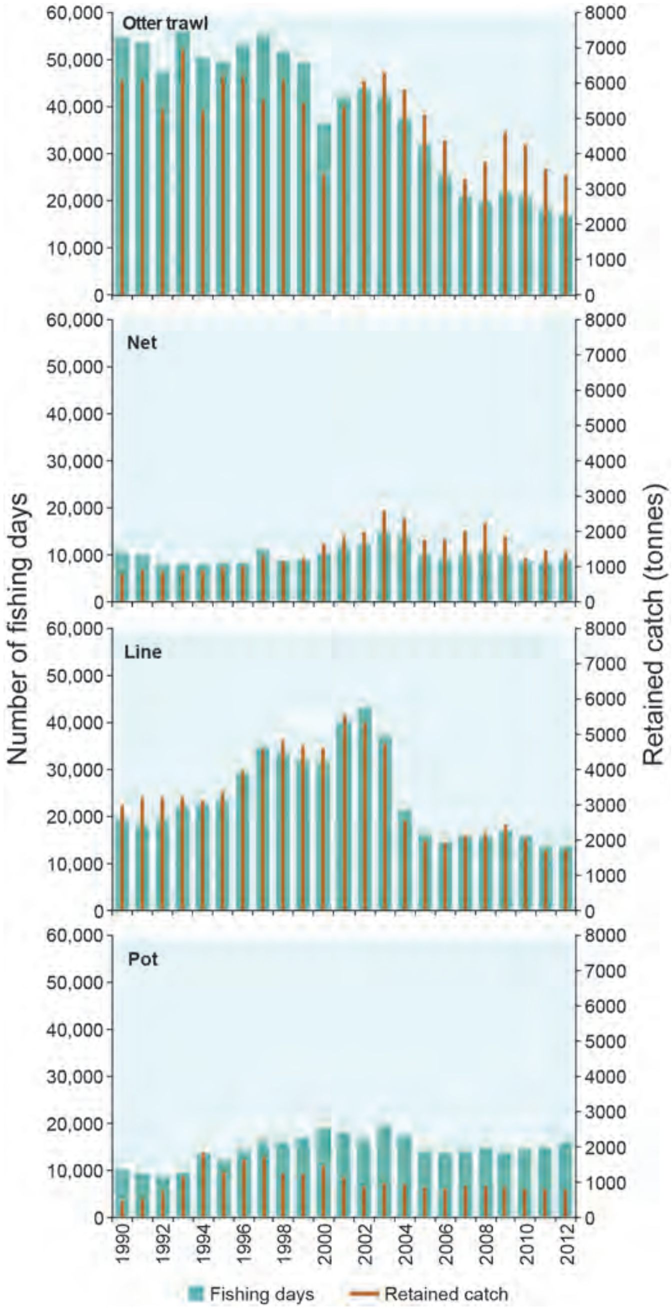

Figure 5.12 Trends in major fisheries, 1990–2012
Annual commercial fishing catch and effort for the Great Barrier Reef Region from 1990 to 2012 for the four major fisheries. Source: Data is based on commercial fisher logbook records. A day of fishing effort has not been standardised over time and does not account for changes in fishing power (such as technology advances and fishing efficiency). Source: Department of Agriculture, Fisheries and Forestry (Qld) 2013[28]

For example, the areas affected by cyclones such as Hamish in 2009 and Yasi in 2011 are reported to have significantly reduced catch rates of coral trout. This can have flow-on effects on other areas. After cyclone Hamish some active commercial live coral trout fishers moved their operations northward away from the cyclone-affected areas.[32] The commercial catch rates of coral trout, though recovering in some areas, have generally remained depressed since these cyclones.[28]

There have been changes in the distribution of annual catch within the four main commercial fisheries in the period 2009 to 2012, compared to 2005 to 2008.[28] Areas where catch has changed by around 50 per cent or more include:

- Trawl — catch increased in the deep-water trawl area adjacent to the Swain Reefs; inshore areas adjacent to Gladstone; the area adjacent to Mackay; Bowen; and offshore Hinchinbrook. Decreases occurred in the southern Great Barrier Reef and Capricorn–Bunker Group area; the Burdekin and inshore Hinchinbrook regions; and slightly in all trawlable areas north of Cooktown.

- Net — catch increased in the Babinda, Hinchinbrook, Bowling Green Bay, Bowen, Whitsunday, Mackay and Town of 1770 areas. The most significant decreases in catch occurred from Cairns north to Cape Grenville, just south of Cape York, with marked decreases also occurring in the Upstart Bay, Broadsound, Shoalwater Bay, Keppel Bay and Gladstone regions.
- Line — catch increased in nearly all fishable reef areas from Cairns to Cape York, with marked increases of over 100 per cent in most fishable grids from Port Stewart to Cape York. In contrast, catch decreased for most areas of the eastern Swain Reefs area and offshore reefs east of Mackay, Bowen and Townsville.
- Pot — spanner crab catch declined significantly in the Region's far south lagoonal and deeper waters. Mud crab catch increased in the Hinchinbrook, Bowen and Whitsunday areas, with average annual catch in the most important mud crab producing area of Bowling Green Bay more than doubling in recent years. Decreases occurred in the Cairns, Mission Beach, Townsville, Upstart Bay, Shoalwater Bay and Keppel Bay areas.

Fishing extracts mostly predators and particle feeders.

Commercial fishing harvests many species, across multiple ecological groups. Figure 5.13 shows the breakdown by ecological group for retained catch in the four largest commercial fisheries.

Increasing fuel prices and the loss of crew to alternative opportunities related to mining continue to affect profitability[33] and, in some cases, areas of operation of Great Barrier Reef fisheries. The strength of the Australian dollar has also put pressure on commercial fisheries. In this economic environment, exported product is less profitable and there is increasing competition in the local market from cheap imports. However, as many wild-caught fisheries throughout the world continue to be fully exploited or over exploited[34], the economic value of the Region's fisheries resources may increase.[5] International demand for wild-caught Queensland seafood may increase pressure to further exploit currently fished resources (legally and illegally), target additional species, and develop intensive aquaculture within the Region and its catchment.[5] Expected growth in aquaculture around the world[35] (for example, aquaculture-raised coral trout are expected to be commercially viable in the near future[36]) may also lead to diversification within the Coral Reef Fin Fish Fishery.

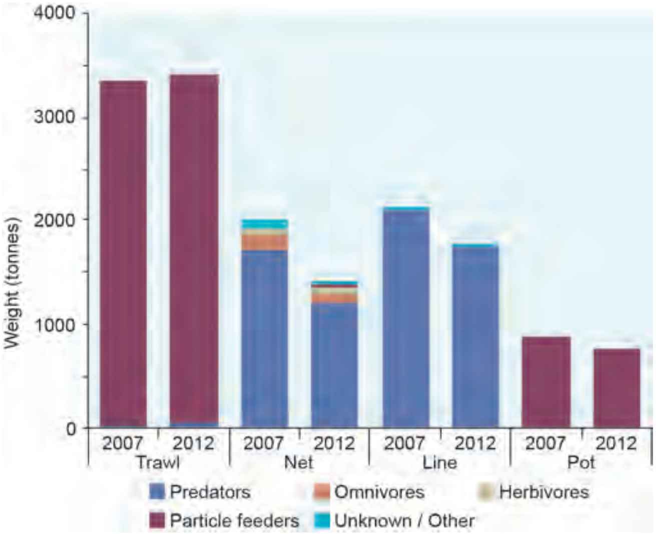

Figure 5.13 Ecological groups retained by major commercial fisheries, 2007 and 2012
By far the majority of species retained by commercial fishing in the Region are predators and particle feeders. Data is for commercial retained catch only. Discarded catch and bycatch are not included. 'Particle feeders' includes filter feeders, detritivores and scavengers. Source: Department of Agriculture, Fisheries and Forestry (Qld) 2013[28]

Management The *Great Barrier Reef Marine Park Zoning Plan 2003* applies to all fishing activities. It specifies areas that can be fished and the type of fishing that can be undertaken. It results in about two-thirds of the Great Barrier Reef Marine Park being available for various types of fishing. It allows trawling in about one-third of the Marine Park.

Global trends may increase pressures on fishing activities and the environment.

Subject to meeting the requirements of the Great Barrier Reef Marine Park Act, including the overarching objective of long-term protection and conservation, the Offshore Constitutional Settlement[37] provides for fisheries management within the Region to be undertaken by the Queensland Government. The fisheries are included in statewide management arrangements under the *Fisheries Act 1994 (Qld).* Under the *Great Barrier Reef Intergovernmental Agreement 2009*, the Australian and Queensland governments are undertaking an integrated and collaborative approach to management. A key aim is ecologically sustainable fishing in the Region.

The Queensland Government has a core role in managing fishing.

For commercial fishing activities, direct management arrangements include commercial fishing licences for all operators, total allowable commercial catch limits (quotas) for some species, fish size and possession limits, restrictions on fishing apparatus, closed areas and seasonal closures. Species for which quotas apply include tropical rock lobster, trochus, coral, grey mackerel, Spanish mackerel, shark, coral trout, red throat emperor, and all other coral reef fin fishes. For some commercial fisheries, such as the marine aquarium fishery and developmental fisheries, Marine Parks permits are also required. The Queensland shark control program is required to have both Queensland and Marine Parks permits.

A trawl fishery effort cap is in place for the Region; however, current levels of effort could approximately double before the current cap is reached.

The management arrangements for most commercial fisheries in the Region are accredited against the guidelines for the ecologically sustainable management of fisheries[38] under the *Environment Protection and Biodiversity Conservation Act 1999*.

The accreditation process is designed to assess the environmental performance of fisheries and promote ecologically sustainable management. All accreditations in the Region are subject to conditions and recommendations.

Since the Outlook Report 2009, a competitive annual total allowable commercial catch for shark species has been introduced. In addition, collection of basic information about shark species that interact with this fishery has improved[39,40,41] with stock assessments of selected shark species taken in this fishery due for completion in 2014[42]. However, fishers' logbook reporting is no longer verified following cessation of the independent fishery observer program and there are no mechanisms to warn that the annual total allowable commercial catch is close to being reached.

Recreational fishing is subject to gear restrictions, size and possession limits and seasonal closures. Charter fishing operations operating in the Marine Park require both a Queensland licence and a Marine Parks permit.

Some fish spawning aggregations are protected by seasonal closures under Queensland Government legislation or by marine park zoning.

Fisheries management arrangements are subject to ongoing amendment. Over the past 20 years, there have been extensive changes with the aim of improving the sustainability of the state's fisheries. Key reforms have been around reducing and constraining capacity and the introduction of the legal mechanisms to enable continuous improvement in management. Examples include:

- Capping commercial fishing licences and fishery symbols over recent decades has led to a steady decrease in the number available; however, some latency and overcapacity issues remain for some fisheries in the Region.
- The number of participants and fishing days in the otter trawl fishery has more than halved since the late 1990s (Figure 5.12). Reforms in this fishery, principally in 2000, included the introduction of effort units into the fishery, satellite tracking of vessels, and a number of gear changes including mandatory use of turtle excluder devices.
- The first two phases of the Queensland Government voluntary netting buyback scheme had, in early 2014, bought back 69 commercial netting symbols plus a number of other fishery symbols.
- Management reforms to the Coral Reef Fin Fish Fishery in 2004 and the East Coast Inshore Fin Fish Fishery in 2009.

A major review of the Queensland Government's fisheries management arrangements was announced in March 2014.

Through the joint Field Management Program, the Australian and Queensland governments work cooperatively in fisheries compliance in the Great Barrier Reef World Heritage Area, including surveillance and other enforcement activities. Fisheries compliance staff operate from eight bases adjacent to the Region.

5.4.2 Benefits of fishing

Commercial fisheries have been operating in the Region for many decades and have played an important role in the development of regional Queensland. Fisheries product from the Region continues to be important to local communities, as well as domestic and international markets. A very high proportion (around 90 per cent) of the Queensland coastal population consumes fresh seafood.[43] In a 2008 survey, many consumers reported they preferred Queensland, wild-caught species, despite it being more expensive than imported seafood products, and many believed it would benefit their community and the Australian economy.[43] Fisheries within the Region continue to contribute a major component of Queensland's total seafood catch. In 2012 it represented about 52, 80, 21 and 30 per cent of Queensland's retained catch in the trawl, line, net and pot fisheries, respectively (Table 5.2).

Commercial fishing and aquaculture in and adjacent to the Region generates about $160 million per year.

In 2011–12 the economic contribution of the commercial fishing and aquaculture industries of the Region and its adjacent catchment to the national economy was estimated to be $160.3 million (Table 5.1).[2] This value-added figure is the gross value of production minus tax on production and other factors such as operating costs and labour. Separate recent valuations of the major fishery sectors (calculated on the price paid to fishers at the first point of sale) reported the value of the East Coast Inshore Fin Fish Fishery to be about $19.6 million per year[44], the reef line fishery about $31 million per year[45] and the trawl fishery about $110 million each year[46]. In 2012, commercial fishing in the Region was estimated to have generated the equivalent of 975 full-time jobs.[2]

The coral and marine aquarium collection fisheries collect a vast array of fishes, corals and invertebrates to supply domestic and international markets.[47] The gross value of production of this fishery is estimated to be roughly $10 to $12 million dollars per annum.[47]

Commercial fishers continue to have a high attachment to their industry, and most have been involved in the industry for more than 20 years.[48,49] Generally they are very reliant on the industry, with most fishers receiving more than 75 per cent of their household income from fishing.[49,50] Commercial fishing is more than just a job for most fishers. In a 2008 survey of inshore commercial fishers in the Region, 63 per cent preferred to be at sea than on the land; 98 per cent stated they liked being a fisher; 93 per cent stated fishing is a lifestyle, not just their job; and 79 per cent felt proud to tell others they were a commercial fisher. Seventy per cent also stated they would still be fishing in three years.[48]

Recreational fishing is one of the most popular recreational pastimes in the Region, and contributed significantly to the $243.9 million[2] generated by recreational users in 2011–12 (Table 5.1). People enjoy recreational fishing in the Region for many reasons, apart from the opportunity to catch local fresh fish. These include appreciating the Region's natural beauty, opportunities for wildlife watching, personal relaxation, and opportunities to spend time with family and friends.[51]

Recreational fishing is one of the most popular pastimes in the Region.

Charter fishing operations provide opportunities for people to participate in recreational fishing within the Region and contribute to local economies.[52]

The Queensland shark control program provides protection to bathers by reducing the risk of a shark attack at popular swimming beaches.

Fisheries product from the Great Barrier Reef is important to local communities

5.4.3 Impacts of fishing

Fishing is the largest extractive use of the Region. The harvest of fisheries resources affects the abundance of targeted species and there are community and scientific concerns about the status of some targeted species.[42,53,54] There are also concerns for the sustainability of fishing spawning aggregations, illegal fishing activity, discarded catch and marine debris associated with fishing activities.

Predators (such as coral trout, mackerel and sharks) make up about half of the retained catch in the four largest commercial fisheries (Figure 5.13), and make up a large percentage of recreational fishing catch[27]. The Queensland shark control program contributes to the extraction of predators; in the last decade between 521 and 716 sharks were removed each year from Queensland waters.[55]

The Outlook Report 2009 highlighted the limited information on the identity and quantum of different shark species caught in the East Coast Inshore Fin Fish Fishery and the general impacts of fishing on some species of sharks and rays. A wide range of shark species is captured by, or interacts with, fisheries (and the shark control program) in the Region and there is a paucity of information about the status of their populations. The most recent annual fisheries stock status report assesses the collective grouping of shark species harvested in the Region as 'undefined'.[42] Several of the species taken in the East Coast Inshore Fin Fish Fishery are now not considered at high risk from fishing. However, some species at risk are still being caught such as the green sawfish, Australian blacktip and pigeye shark.[41] In 2005, an estimated 182,000 sharks were caught by recreational fishers in Queensland, with a release rate of approximately 84 per cent.[56]

The status of most targeted species is not well known.

Pink snapper are classified as 'overfished'[42], and the stock status of coral trout was downgraded in 2012 from 'sustainably fished' to 'uncertain' due to depressed catches and catch rates.[42] The stock status of over half the 65 Queensland east coast fisheries resources that have been assessed are currently classified as 'uncertain' or 'undefined', including commercially and recreationally important king threadfin, barred javelin, and grey mackerel. The status of other important fishery species, including golden snapper (fingermark), giant queenfish and black jewfish, are not assessed by Fisheries Queensland.[42] In a recent ecological risk assessment[41], king threadfin are assessed as being at very high risk, and giant queenfish, black jewfish and barred javelin as being at high risk.

Reductions in predator populations can have long-term effects on the food chain.

Reductions in predator populations can have long-term effects[57], including direct and indirect effects on the food chain (see Section 3.4.5).[58] Changes in predator abundance and behaviour causes changes throughout trophic levels which modify food webs, indirectly acting upon herbivore populations that maintain coral substrates.[59]

Predators make up half the retained catch

Over half of the weight of the retained commercial catch is comprised of **particle feeders** (such as prawns and scallops) which fulfil a range of ecosystem roles such as providing prey for other species and assisting with nutrient cycling. Fishing causes lower abundances of some particle feeders, particularly in more heavily trawled areas. The flow-on effect of extraction of particle feeders may include net loss of nutrients from the ecosystem and changes to other ecosystem processes (for example predation through changed feeding opportunities). The amount of effort in the trawl fishery is the main determinant of impacts on particle feeding in the Region. While effort has been relatively low for about the last decade, risks could increase if effort levels rise.[53]

Recent research has raised concerns about the sustainability of the Region's sea cucumber fishery, especially in the light of recent shifts in the species harvested (Figure 5.11).[30] It suggests that the fishery has developed faster than the science and policy necessary to ensure sustainable harvesting. Without adequate management, stocks may be reduced to below critical thresholds of recovery — a global pattern in tropical sea cucumber fisheries.[30]

The potential impacts from the **coral** fishery are very localised[60] and appropriate management practices are in place, including an industry stewardship action plan[61]. As part of this plan, a voluntary moratorium on coral collecting around the Keppel Islands has been implemented after reef degradation from flooding and coral bleaching.[5]

In addition to the extraction of the retained catch, fishing has additional effects through the death, injury and stress of **discarded species**.[29,62,63,64] Discarded species (other than those of conservation concern) include:

- otter trawl — undersize target species, small fishes, other crabs and prawns, other benthic invertebrates
- net — undersize and oversize target fish species, non-target fish species, non-target sharks and rays
- line — undersize and oversize target fish species, discarded legal target fish species, non-target fish species, non-target sharks and rays, octopus
- pot — undersize male crabs, no-take female crabs, fish species, molluscs, rays
- dive-based collection — little or no bycatch
- recreational fishing — undersize and oversize target species, discarded legal target fish species, non-target species
- shark control program — non-target shark and other species.

Fishing practices and management continue to improve; more can be done.

Management requirements in the trawl fishery, such as the requirement to install bycatch reduction devices and turtle excluder devices, combined with lower trawl fishing effort have reduced the death of discarded catch in this fishery including marine turtles, large sharks and rays.[65,66,67] However, a recent ecological assessment found a range of species are still subject to high and intermediate levels of risk from trawling.[53] Many smaller species of sharks and rays remain in the bycatch of prawn and scallop trawlers. Eleven species of skates and rays (a shovelnose ray, a coffin ray, three species of stingrays, two species of stingarees, three species of skates and a butterfly ray) have been identified as at high risk from incidental catch in the trawl fishery[53] and little is known of their population status and trend. Survival of sharks and rays after being caught in trawl nets and then discarded is often poor.[53] Changes to levels of fishing effort are likely to be the most important aspect of the fishery for mitigating risks to sharks and rays as this influences level of interaction, and current bycatch reduction devices are ineffective for these species.

Fishery observer information for the Region's commercial fishery focused on deep-water eastern king prawns indicates immediate shark and ray survival of 35 per cent on average, and only 17 per cent were released alive.[53] Of the large number of sea snakes caught as trawl bycatch each year (estimated to be over 100,000), it is estimated that about 26 per cent die.[67]

Contemporary estimates of bycatch and discard are lacking in most fisheries.

Except for species of conservation concern, commercial fishers are not required to report discards of targeted species and most bycatch species, and there are no contemporary estimates of the quantum of bycatch and discard. The limited data are fragmented or old. There are currently no arrangements in place to collect data that would enable such estimates to be produced.

Marine turtles can be incidentally caught in fishing nets
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Table 5.3 Fisheries interactions with species of conservation concern, 2006–2012
Interactions reported are as recorded in Species of Conservation Interest (SOCI) logbooks completed by fishers in each major commercial fishery between 2006 and 2012. Interactions include any form of contact or behaviour change of an animal due to the presence of fishing gear. The dataset does not give a complete list of species and gear interactions for the Region. Source: Department of Agriculture, Fisheries and Forestry (Qld) 2013[28]

Species	Major commercial fishery gear type			
	Otter trawl	Net	Line	Pot
Crocodile — estuarine		●		
Crocodile — unspecified		●		●
Dolphin — offshore bottlenose		●	●	
Dugong		●		
Gannets and boobies	●			
Sawfish — dwarf				
Sawfish — green	●			
Sawfish — narrow	●	●		
Sea snake — unspecified	●	●	●	
Seadragon — leafy	●			
Seahorse — unspecified	●			
Turtle — flatback	●			
Turtle — green	●	●		
Turtle — hawksbill	●	●		
Turtle — loggerhead	●	●		
Turtle — saltwater unspecified	●	●	●	
Whale — humpback		●	●	
Whale — minke			●	

Species of conservation concern continue to be impacted by fishing.

There has been a significant reduction in the ecological impacts of the trawl fishery since the 1990s due to changes in management arrangements.[53] However some concerns remain, particularly for the skates and rays mentioned above, two species of Balmain bugs, and two species of sea snakes.

A significant ecological impact on the Region's values from commercial fishing is incidental capture, entanglement and death of **species of conservation concern**, including inshore dolphins, dugongs and turtles (Table 5.3). The magnitude of these impacts may be underestimated because most interactions are unreported despite being mandatory[68].

Species of conservation concern are also impacted by the Queensland shark control program. Nets set for sharks have caught species including dugongs, inshore dolphins and marine turtles (mostly green turtles) and the program's drumlines have caught marine turtles (mostly loggerhead turtles). In most locations, nets have been replaced with drumlines, significantly reducing impacts on marine mammal populations.[69]

The loss of even a small number of individuals of some vulnerable species, such as dugongs, Australian snubfin dolphins, and Indo-Pacific humpback dolphins, may have significant implications for their population status, resilience and rate of recovery from past impacts.[70,71]

Concern remains over the potential impacts of fishing spawning aggregations that are not protected by seasonal closures (for example, grey mackerel[72,73]). Aggregations are in decline globally, with many decreasing or wiped out due to overfishing.[74] Within the Region, it is likely that many spawning aggregations of coral reef fin fish species are protected by zoning arrangements and some benefit from short seasonal closure periods (two five-day closures per year). For inshore species, while spawning aggregations are protected to some extent by the current zoning arrangements, it appears that the protection afforded is less extensive than for coral reef fin fish species. In addition, for aggregations other than barramundi, inshore species are not protected by seasonal closure periods. Relevant species include grey mackerel, golden snapper, barred grunter and black jewfish (the last two are assessed as being at high ecological risk[41]). Loss of fish spawning aggregations leads to declines in fish populations through reduced recruitment, with negative ecological consequences.[75] Spawning aggregations are recognised as a natural phenomenon that contributes to the Reef's outstanding universal value.[76]

Fishing activities can also cause **physical damage** to the seabed and reef habitats. For example, trawl gear can cause direct physical impacts on habitats, such as altering the vertical relief of seabed features and redistributing sediments, and removing or damaging seabed plants and animals.[77,78,79,80,81,82] Line fishing gear can cause physical damage to live coral tissue and coral colonies.[83]

Additionally some of the small vessels that have accidentally run aground and damaged reefs and shoals have been commercial and recreational fishing vessels.

Illegal fishing remains a concern, especially intentional targeting of protected zones.

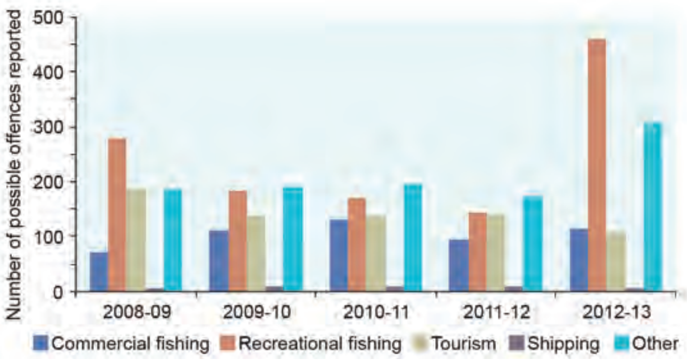

Figure 5.14 Possible offences reported to the Field Management Compliance Unit, 2008–09 to 2012–13
Possible recreational fishing offences are the most commonly reported. The spike in 2012–13 reflects a greater surveillance focus. (Note: 'Other' offences include those related to vessel groundings, pollution, recreational not related to fishing (e.g. island national park offences), wildlife, research and moorings). Source: Great Barrier Reef Marine Park Authority[87]

Fishing activities, both inside and outside the Region, can contribute to **marine debris** through loss of gear.[84,85]

Illegal fishing can cause serious effects on the Region's ecosystem, especially by compromising the effectiveness of the zoning arrangements.[86] Based on knowledge gained through compliance and enforcement activities and on field intelligence, high priority areas for enforcement include non-compliance with zoning requirements within the Coral Reef Fin Fish Fishery, and with netting requirements in the East Coast Inshore Fin Fish Fishery. Reliable information indicates illegal activity in the Coral Reef Fin Fish Fishery continues to be significant despite the recent low number of offences detected.

Non-compliance in recreational fishing accounted for the most frequently reported offence types in 2012–13 with fishing in Marine National Park zones increasing from 144 in 2011–12 to 459 in 2012–13 (Figure 5.14). This trend has continued during the first half of 2013–14. The increase reflects the greater surveillance focus owing to concerns around flow-on ecosystem effects and the intentional targeting of protected zones by some fishers. Night-time fishing is a growing challenge for surveillance. While cooperative planning of patrol effort has always been a focus of the compliance program, there have been significant recent enhancements in intelligence sharing and coordination between partner agencies in delivering patrols at the times and locations of highest risk.

Indigenous heritage values can be affected by fishing.

As well as affecting the ecosystem, the effects of fishing have flow-on implications for the Region's **Indigenous heritage values**. Reduced populations of species affected during fishing activities can mean Traditional Owners' ability to catch food is diminished, resulting in a break with cultural practice, lore and custom, and interference with sites of particular cultural significance. Extraction of predators can also affect Indigenous heritage values. For example, in the northern town of Injinoo, a key food source of Traditional Owners, the black jewfish, is now found in much lower numbers and in much smaller sizes. This affects the ability of Traditional Owners to maintain their cultural practices and customs. This decline has been attributed to fishing pressure.[88] Any depletion of culturally significant species including dugongs, green turtles, sea snakes, sharks, rays, crayfish, mullet, oysters, pipi, clamshells, whiting and bream can have direct effects on Indigenous heritage values such as cultural practices, observances, lore, stories, songlines and sites. Taking culturally significant species at the wrong time of year, in the wrong numbers or at culturally sensitive sites reduces the numbers available for use in traditional ways and forces Traditional Owners to change their customs and practice.[88]

Although a legacy activity, past commercial harvesting of herbivores, such as green turtles and dugongs, has ongoing effects on Indigenous cultural values and has significantly changed cultural practices. The low population size, in part due to the previous commercial harvests, limits the number of animals available for hunting, as well as changing where animals occur.[89]

5.5 Ports

5.5.1 Current state and trends of ports

Great Barrier Reef ports account for about three-quarters of Queensland's port throughput.

There are 12 ports in or adjacent to the Region (Figure 5.15). Of these, eight are located at least partly in the Region and only the minor ports of Cooktown and Quintell Beach in Cape York are located within the Marine Park. In 2011–12, ports within or adjacent to the Region accounted for 76 per cent of the total throughput for all Queensland ports combined. This amounted to 199.8 million tonnes of imports and exports through the Region, up from 191.5 million tonnes in 2008–09.[90] In that same year, for all Queensland ports combined, coal made up 63 per cent of the throughput volume, petroleum products six per cent, and metals and minerals five per cent.[91] Other commodities include agricultural products, and general cargo.

The four busiest ports in relation to commercial vessel visits in 2011–12 were Gladstone (1453 visits), Hay Point (809 visits), Townsville (747 visits) and Cairns (720 visits).[90] In terms of infrastructure and operational capacity, the largest ports on the Region's coast are Abbot Point, Gladstone, Hay Point and Townsville. Over the last decade, the total throughput of these ports has increased (Figure 5.16). The Gladstone, Abbot Point and Hay Point ports are major hubs for the export of coal.[92] Hay Point is one of the largest coal export terminals in the world[93], handling more than 80 million tonnes of coal in 2011–12.[90] During 2010–11, it had the highest value of coal exports among all Queensland ports at $18 billion.[94]

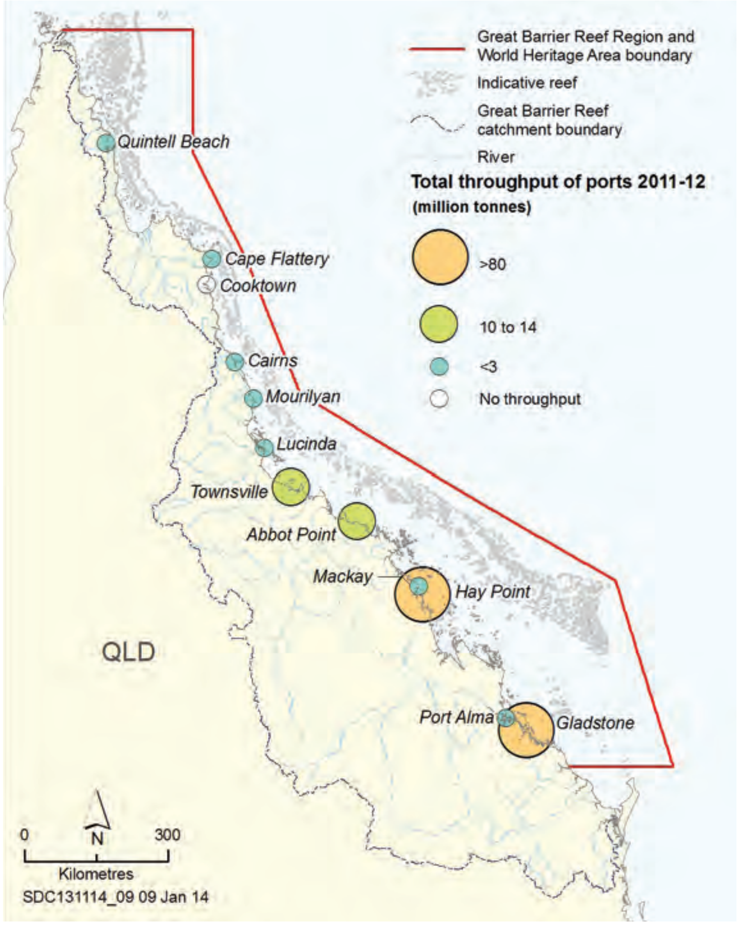

Figure 5.15 Total port throughput, 2011–12
In 2011–12, ports within or adjacent to the Region handled 76 per cent of the throughput for all Queensland ports. Cargo throughput (in millions of tonnes) is imports and exports combined. Source: Ports Australia 2012[90]

There has been major growth in port activity on the Region's coast over the past two decades.[95] Increases in bulk commodity exports from these ports are driving increases in shipping. As at February 2014, four of the 12 ports (Cairns, Townsville, Hay Point and Gladstone) had active proposals for port expansions, driven mainly by growth in the resources sector. During 2012 and 2013 there were proposals for the development of three new ports along the Region's coast (Wongai in Cape York, the Fitzroy terminal project, and Balaclava Island — now withdrawn). Not all current proposals may proceed.

Dredging — the extraction of parts of the seafloor to deepen an area for improved access — has been undertaken in ports and associated access channels for many decades but now involves much greater volumes. Today, both capital and maintenance dredging are undertaken within and adjacent to the Region, including in large-scale programs at major ports, smaller scale programs at minor ports and to provide access to islands within the Region. Most large-scale dredging and dredge material disposal are associated with the larger and busier ports such as Townsville, Abbot Point, Mackay, Hay Point and Gladstone.[94]

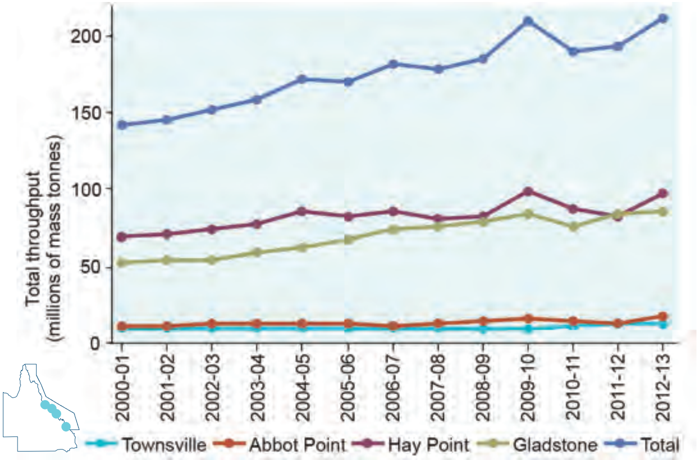

Figure 5.16 Throughput of four major ports, 2000–01 to 2012–13
Over the last decade, the total throughput (imports and exports) of the four major ports has increased, especially the ports of Gladstone and Hay Point. Source: Ports Australia 2012[90] and Department of Transport and Main Roads (Qld) 2014[96]

Dredge material (sediments and other material from the seafloor) may be disposed at sea or on land. Some permitted ocean disposal sites are located within and adjacent to the Region. Between 2001 and 2013, the total volume of dredge material (from both capital and maintenance dredging) disposed in the Great Barrier Reef World Heritage Area was approximately 28 million cubic metres (Figure 5.17). In January 2014, a proposal for Abbot Point was approved to dispose of three million cubic metres. Proposals involving sea disposal

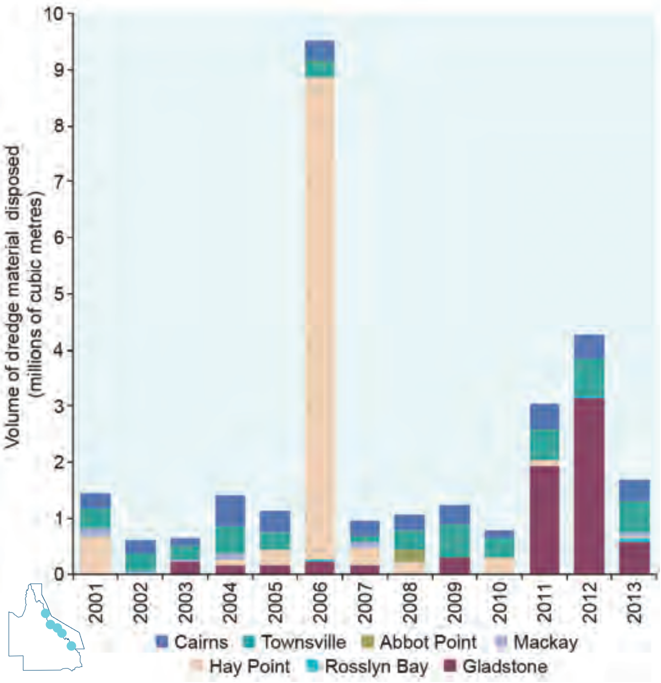

Figure 5.17 Dredge material disposal, Great Barrier Reef World Heritage Area, 2001–2013
The graph shows volumes of dredge material disposed in the Great Barrier Reef World Heritage Area between 2001 and 2013. Source: Data derived from the International Maritime Organisation sea disposal reports submitted to the Great Barrier Reef Marine Park Authority and Australian Government Department of the Environment

in the Great Barrier Reef World Heritage Area that are currently under assessment include (but are not limited to): Cairns shipping development project (five million cubic metres); Townsville port expansion (5.7 million cubic metres); and expansions of the Dudgeon Point coal port facility (up to 13 million cubic metres) and the Port of Gladstone (up to 12 million cubic metres).

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

The International Maritime Organisation requires that Australia, as a party to the *International Convention for the Prevention of Pollution from Ships (MARPOL) Annex V*, provides adequate waste reception facilities at all ports. Ships are encouraged to report ports that do not provide an adequate service, which are then investigated and reported to the International Maritime Organisation.

Proposals for port development, including dredging and disposal of dredge material in the Region, are assessed under Commonwealth and Queensland legislation including the Environment Protection and Biodiversity Conservation Act, the Great Barrier Reef Marine Park Act and the *Environment Protection (Sea Disposal) Act 1981*, as appropriate. The *National Assessment Guidelines for Dredging 2009*[97] are considered in assessing applications.

The *National Ports Strategy*[98] includes initiatives to improve integrated planning and environmental management regimes. The 2014 *Queensland Ports Strategy*[99] is expected to critically influence future planning and management of ports in and adjacent to the Region, including environmental protection arrangements. The Strategy foreshadows that significant port development will be prioritised and consolidated in major port areas, restricting significant port development (within and adjoining the Great Barrier Reef World Heritage Area) to within existing major port limits for the next 10 years until 2022.[91]

The Great Barrier Reef Marine Park Authority has a policy[100] that guides assessment and management processes for dredging and dredge material disposal. It includes restrictions on: the location of dredging and dredge material disposal; contaminated dredge material disposal; and annual volumes of sea disposal within the Marine Park. It supports long-term planning to minimise impacts.

5.5.2 Benefits of ports

The economic contribution of Great Barrier Reef ports is increasing.

As an island nation, Australia is dependent on maritime trade. Consequently, ports and their associated infrastructure are of significant economic and social importance to Australia. A number of Queensland's ports, including those in and adjacent to the Region, are nationally significant for cargo throughputs[90] and contributions to the national economy. The value of goods shipped from ports adjacent to the Region is approximately $40 billion each year.[101] Their increasing throughput makes it likely that the economic contribution of Great Barrier Reef ports has increased since 2009.

5.5.3 Impacts of ports

Impacts to the marine environment from the installation and maintenance of port infrastructure and general port operations include clearing and modifying coastal habitats; disturbance, displacement, dredging, disposal and resuspension of dredge material; injury and death of wildlife; the risk of large and small chemical and oil spills; some contribution to marine debris; altered light regimes; and diminished aesthetic values. Noise pollution associated with general port activities such as pile driving may be affecting marine life[102]. However little is known of its effects in the Region. High concentrations of coal dust have been detected around a loading facility[103], but the potential effects of this and any other port-generated atmospheric pollution are not well understood.

Dredging and dredge material disposal have local adverse environmental impacts.

The Outlook Report 2009 stated 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. Since 2009, understanding of the effects of dredging and the disposal and resuspension of dredge material has advanced, although broader regional and cumulative effects on inshore biodiversity remain poorly understood. Many of the inshore environments in which ports operate are already under pressure from an accumulation of other impacts such as those associated with land-based run-off, shipping and coastal development. There is also increased community interest in this activity and its potential effects.

The specific effects of dredging activities are well documented and include: seabed disturbance[104,105]; removal or modification of seafloor habitats[106,107]; loss of species, including benthic organisms[93] and injury or mortality to species of conservation concern[104,108]; changes in species behaviour[109]; degradation of water quality[106,110] including increased sedimentation and turbidity from dredge plumes[105]; changes to hydrodynamics and coastal hydrology[105]; increased underwater noise[102]; and an increased risk of oil spills[109]. The most severe effects are at the site of dredging but some, including sedimentation, turbidity, noise and disruption of fish habitats, may also occur some distance from the site. With regard to heritage values, there can be sea burial sites, sacred sites and sites of other cultural significance in the areas where dredging is undertaken and, previously, inadequate consultation with Traditional Owners has meant some of these values have been affected.[111] In addition, dredging activities can disturb Indigenous cultural practices[112]. Aspects of the Region's aesthetic value such as 'beauty', 'naturalness' and 'remoteness' are considered highly sensitive to industrial development including ports.[113]

Major direct impacts of sea disposal of dredge material include the burial or smothering of plants and animals on the seafloor[106], degradation of water quality[93], and loss and modification of habitats[105]. There is also emerging evidence of a higher prevalence of coral disease in areas exposed to dredge material.[114]

Understanding of the extent to which dredge material remains within the defined disposal area has improved.[115,116] Modelling in a recent screening-level analysis of potential disposal areas — the first to incorporate the effects of large-scale oceanic currents — suggests dredge material has the potential to migrate over greater distances and for longer periods than previously understood (more than 100 kilometres).[117]

The cumulative effects of dredging and dredge disposal are not well understood.

Dredging and disposal of dredge material can also remobilise, redistribute and resuspend sediments and nutrients that were otherwise held within seafloor sediments. Fine sediments can become resuspended over several years by wind and waves, contributing to increased turbidity.[118,119] Increases in turbidity reduce the light available for photosynthesis, affecting coral and seagrass habitats and species that rely on them.[105] This is particularly significant if these effects happen during periods critical for seagrass survival, growth and reproduction. Increased turbidity also affects coral growth, structure and survival.[110,120]

The consequential impacts of ports are also linked to those associated with shipping and ship anchorages (Section 5.8).

Dredging and disposal can remobilise and resuspend sediments

5.6 Recreation (not including fishing)

5.6.1 Current state and trends of recreation

Recreation is defined as an independent visit to the Region for enjoyment that is not part of a commercial operation. It is distinct from tourism and charter fishing where a visitor pays to use a commercial operation (Section 5.2).

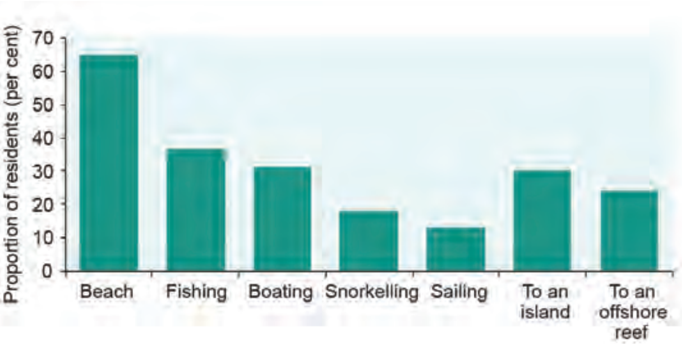

Figure 5.18 Main activities of catchment residents in the Great Barrier Reef, 2013
The graph shows the percentage of residents surveyed who undertake each type of activity more than once a year. Going to the beach was the most popular activity for residents, followed by fishing and boating. Source: Stoeckl *et al.* 2013[13]

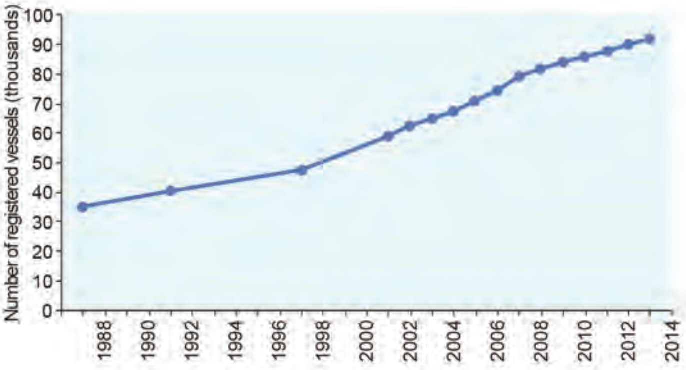

Figure 5.19 Number of recreational vessels registered in the catchment, 1987–2013
The number of vessels registered in areas close to the Great Barrier Reef has continued to increase. Source: Department of Transport and Main Roads (Qld)[25]

People living adjacent to the Region, as well as domestic and international visitors, use the Region for a wide range of recreational activities, including fishing, snorkelling, diving, swimming, boating, beach and island walking, sightseeing, relaxing and socialising. For residents of the catchment, going to the beach, fishing (Section 5.4) and boating were the most popular activities in 2013 (Figure 5.18).[13]

The most popular offshore destinations for recreational visitors to the Region are islands, followed by reefs, shoals, cays and wrecks.[121]

The number of recreational visits from residents in the catchment appears to have risen substantially between 2003 and 2008, most likely as a result of three factors: population growth, an increase in the proportion of the population visiting the Region and a rise in the average number of visits each person makes.[121] It is estimated that 87 per cent of residents in coastal towns adjacent to the Region have visited the area for recreation.[13] The majority of coastal town residents feel there is no better place to undertake the recreation activities they enjoy than the Great Barrier Reef.[26]

There has been a steady increase in vessel registrations over the past few decades (Figure 5.19) which is likely to have translated into more recreational vessel trips in the Region. Townsville and Mackay have the highest numbers of vessel registrations adjacent to the Region (Figure 5.20). Improving vessel and navigational technology has presumably influenced the distribution of recreational activities within the Region.

Management Recreational activities that do not involve fishing can be undertaken in almost all of the Region. Many Australian and Queensland government agencies are responsible for managing aspects of recreational use of the Region. In the more intensively used areas (such as offshore Cairns and the Whitsundays), detailed arrangements for reducing the impacts of recreation (and tourism) are outlined in plans of management, including specifying group and vessel size limits and no anchoring areas. Public moorings are provided throughout the Region at some of the more popular recreational locations. Public education and encouraging users to adopt best practices play 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. The *Recreation Management Strategy for the Great Barrier Reef Marine Park*[122] provides an overarching framework for the management of recreation by the Great Barrier Reef Marine Park Authority.

5.6.2 Benefits of recreation

The opportunity to enjoy the Region's environment is of enormous community benefit.

The opportunity to enjoy the Region's environment is of enormous social and cultural value to Queensland residents, other Australians and international visitors.[122] The Great Barrier Reef is viewed as inspiring, beautiful, amazing and unique by Australians who have already visited the Reef and those who are yet to visit.[1] In 2011–12, recreational activities (including fishing) were the second largest direct use of the World Heritage Area, generating $244 million (value-added), a substantial increase on the estimate of its value in 2006–07 ($153 million). The activities generated employment equivalent of 2724 full-time jobs, up from approximately 1700 in 2006–07.[2,3] Most of the contribution associated with recreational activity was derived from expenditure on equipment, largely reflecting the purchase of boats and maintenance or repair of recreational equipment.[2]

Recreational users contribute to protection and management of the Region's values through programs such as Clean Up Australia Day, Order of Underwater Coral Heroes Volunteers (OUCH), Tangaroa Blue, Eco-Barge, the Strandings Hotline and the Sightings Network.

Undertaking recreational activities in the Region is one of the key ways that its social values are realised. For example, it is principally through recreation that people enjoy and learn to appreciate the Reef environment and gain access to its resources. Visitors often report that they derive health benefits from the Great Barrier Reef environment including being able to 'unwind' and 'get away from it all', release stress, improve their fitness through outdoor activities, and improve their diet through access to wild-caught seafood. Many also report a close personal connection to particular sites in the Region, which is maintained through visiting the sites and enjoying experiences there.[13,26,123] Catchment residents are most satisfied with being able to spend time on the beach, go swimming or diving; boating, sailing and jet skiing; and having undeveloped and uncrowded beaches and islands. Residents rated environmental factors like healthy coral reefs and clear open water as being much more important to their overall quality of life than economic factors (such as benefiting from jobs and incomes related to industries in the catchment and Region) (Figure 5.21).[13]

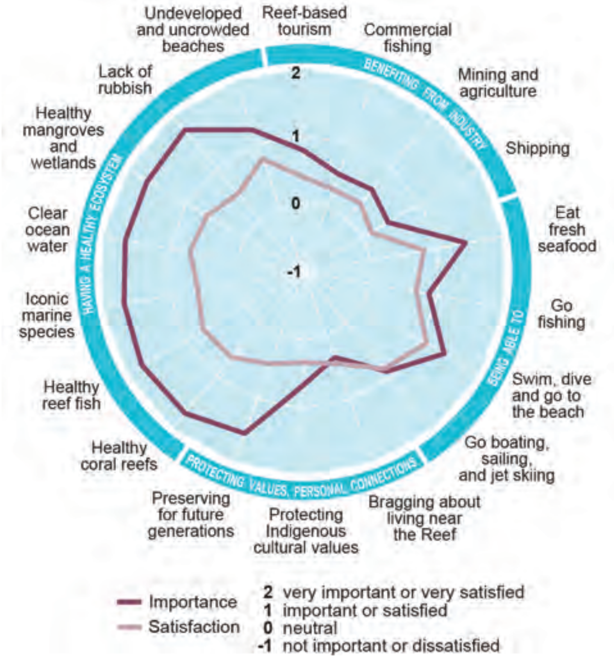

Figure 5.21 Importance and satisfaction of goods and services to residents' overall quality of life, 2013
Residents of the Great Barrier Reef catchment were surveyed (1592 respondents) to determine how important a range of goods and services were to their overall quality of life, and how satisfied they were with them. The circle shows a rating for how important each factor was (the dark red line) compared to how satisfied visitors were with that factor during their visit (the light red line). Factors associated with having a healthy ecosystem, shown on the left of the circle, were identified as being most important. For those factors, mean satisfaction scores were consistently much less than their importance scores. Source: Adapted from Stoeckl *et al.* 2013[13]

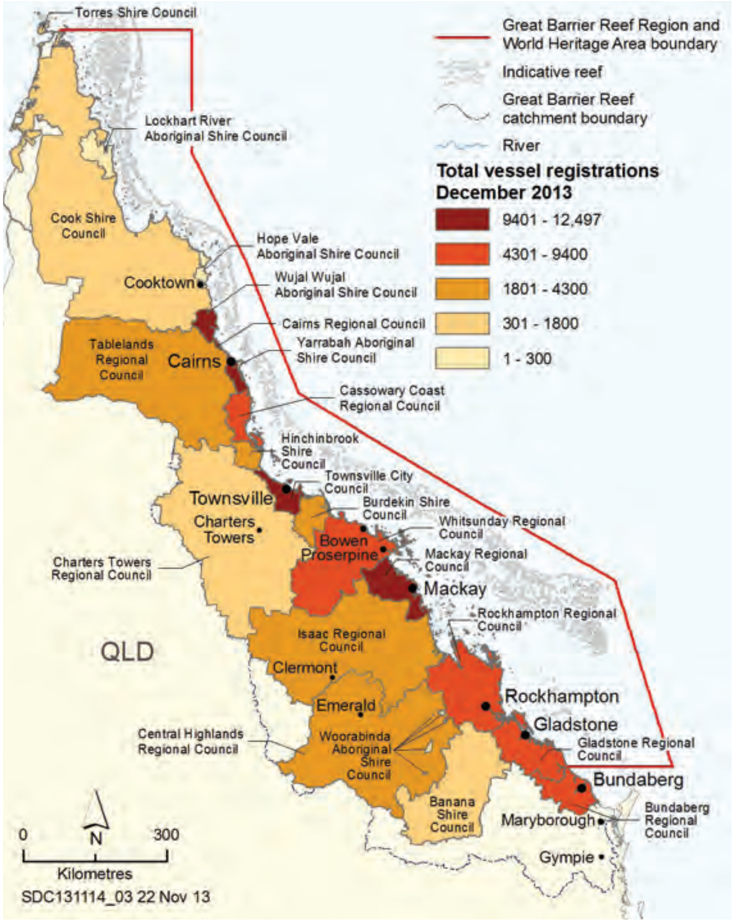

Figure 5.20 Recreational vessel registrations, 2013
Vessel ownership is concentrated in local government areas close to the coast adjacent to the Region. Source: Department of Transport and Main Roads (Qld)[25]

5.6.3 Impacts of recreation

The likely impacts of recreational use relate to both the activities undertaken and the use of vessels to access and travel throughout the Region. Most of the identified impacts are likely to only have minor effects; and be concentrated close to the coast, in popular areas[122].

For activities such as snorkelling and diving, the impacts are most likely to be minor localised damage to corals and disturbance to wildlife. Activities on beaches and islands, including the use of vehicles, can result in disturbance to seabirds and other wildlife, trampling of coastal vegetation and the introduction of weeds and feral animals. Recreational users are also likely to contribute to litter in the Region, both on the water and on islands.

Recreation impacts are mostly close to the coast, close to regional centres.

The impacts associated with the use of vessels are generally similar regardless of whether they are used for recreation or another purpose, for example localised but frequent anchor damage to corals and seagrass meadows; boat strikes on marine mammals and turtles; the risk of introducing

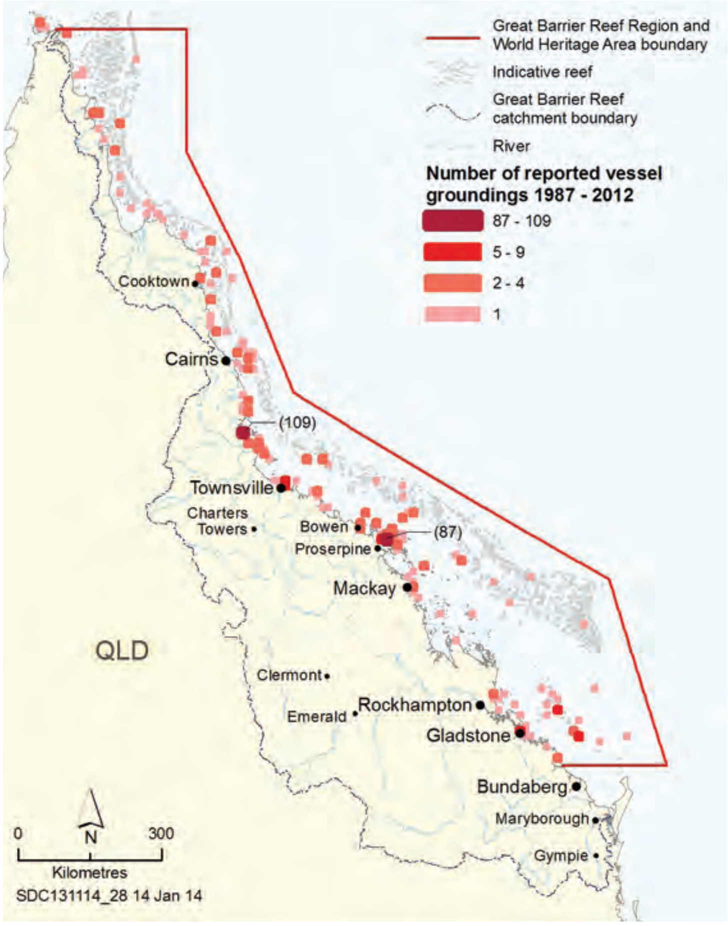

Figure 5.22 Reported vessel groundings, 1987–2012
The locations with a very high number of groundings in the Region over the period are those associated with cyclonic events. Data includes all types of vessels that have grounded or beached.

species through vessel fouling, especially those from overseas; oil and chemical spills; vessel sewage discharge; and disturbance of wildlife.

Vessel groundings, including vessels used for recreation, are reported from throughout the Region, concentrated in coastal areas (Figure 5.22). Most groundings only have a localised impact.

High demand and long wait times at popular access points can result in use being spread to adjacent, less popular areas as people choose to spend more time travelling and less time queuing.[122] Alternatively increasing recreational use could lead to increased localised pressure on some access points close to urban centres.[122]

Any increases in recreational use are likely to increase effects on heritage values, especially in those cases where recreational activities are incompatible with Traditional Owner cultural use of marine resources in their sea country areas.

Compliance incidents associated with recreational activities other than fishing include vessel groundings and sinkings, installing unpermitted moorings, pollution including littering and illegal discharges, entering restricted areas or zones, approaching whales too closely and offences on islands such as camping without a permit, lighting campfires and taking domestic animals ashore.[124]

5.7 Research and educational activities

5.7.1 Current state and trends of research and educational activities

The Great Barrier Reef has historically been an area of high scientific interest because of its biological and ecological diversity, geomorphology and cultural heritage. Scientific research has made a substantial contribution to the way the Region is understood, managed and used.[125,126] Available monitoring results enable tracking of trends in some of the Region's values and in the factors affecting them.[127]

The Region is highly valued for educational and research activities.

A network of six island research stations located at Lizard Island, Low Isles, Green Island, Orpheus Island, Heron Island and One Tree Island continues to be integral to research activities on the Reef. Eighty per cent of scientific research has been conducted around Lizard, Heron and Orpheus islands.[128] The research stations are also a focus for permitted educational use. Over half of the education permits issued between July 2008 and June 2013 were for Heron Island and the adjacent Wistari Reef.[129]

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 issued jointly by the Great Barrier Reef Marine Park Authority and the Queensland Government or through accreditation of research institutions. Educational activities require a permit.

5.7.2 Benefits of research and educational activities

Research and monitoring of the Great Barrier Reef continues to contribute to global knowledge about individual species, coral reef systems and tropical marine ecology. An improved understanding of the Region's values and how its components interact and respond to changing conditions has contributed substantially to its protection and management.[130] In addition, the results of targeted and applied research are providing managers with information to better measure the outcomes of management initiatives.

A range of academic institutions and government agencies undertake research about the Great Barrier Reef, providing income and employment in regional communities. Major institutions include Australian Institute of Marine Science, CSIRO, James Cook University, Australian Research Council's Centre of Excellence in Coral Reef Studies, University of Queensland, and the Australian Museum.

Knowledge derived from research related to the Region has supported management including informing development of *Water Quality Guidelines for the Great Barrier Reef*[131], evaluating the effectiveness of the 2004 Great Barrier Reef Marine Park rezoning[132], and redefining the baseline condition of healthy inshore reefs[133]. In addition, a long-term social and economic monitoring program is being developed and implemented.[134]

Research and educational activities are concentrated around research stations; minor, localised effects are likely.

5.7.3 Impacts of research and educational activities

The concentration of research and educational activities around research stations has the potential to locally deplete some species, disturb wildlife and cause some minor, localised physical damage to habitats. Little is known about the cumulative impacts of research and educational activities at any particular location; however, given the scale of activities, overall impacts are likely to have only localised effects.

5.8 Shipping

5.8.1 Current state and trends of shipping

Thousands of domestic and international ships transit the Region every year, carrying export goods, servicing coastal and inland communities and transporting passengers. Shipping, as described in this report, includes vessels greater than 50 metres in overall length or carrying specialised product regardless of length (for example, oil tankers, chemical or liquefied gas carriers). It includes cruise ships and super yachts.

Shipping use of the Region has increased substantially since 2000 (Figure 5.23), driven mainly by industrial and mining activity. Based on information from the Great Barrier Reef and Torres Strait vessel traffic service (REEFVTS), there were 9619 ship voyages through the Region in 2012–13.[135] This was an increase of about two per cent on the 9403 voyages in 2011–12 (the first year of the extended vessel tracking service). The profile of the ship fleet visiting the Region is changing, with the number of individual ships increasing by an average of 3.4 per cent per annum from 2008–09 to 2012–13 and average carrying capacity rising by four per cent per annum over the same period.[135] Based on projected export capacities, information from existing development proposals and predictions for the Region's four major ports, the number of vessel calls to ports adjacent to the Region is forecast to increase by about 250 per cent over the next 20 years[136] (Figure 5.24). This is likely to be driven by growth in the mining and liquefied natural gas industry, port expansions and increases in trade.[94]

There is also a global trend towards longer, deeper draft ships.[137]

Worldwide, ships are becoming longer with deeper drafts

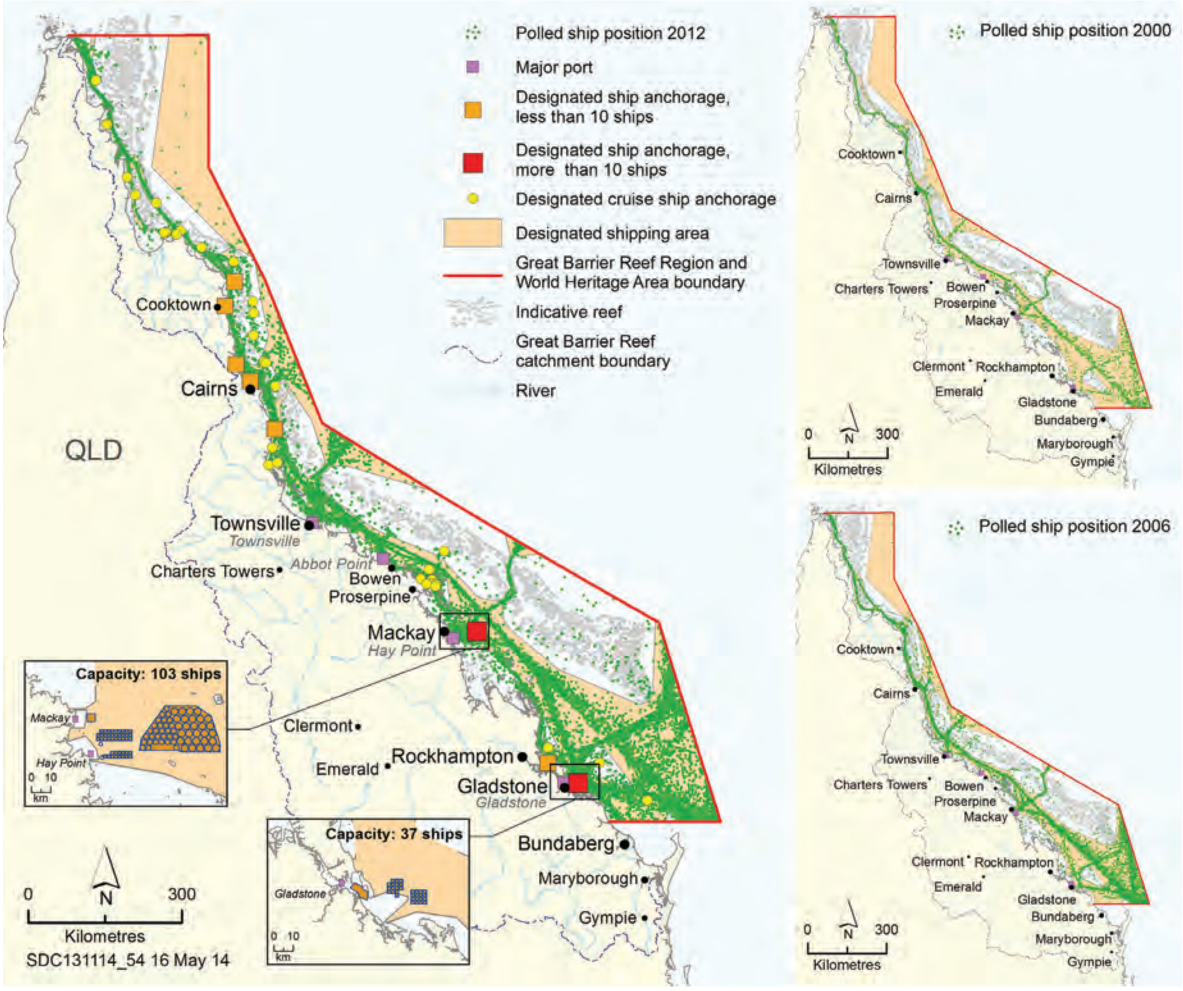

Figure 5.23 Ship anchorages and traffic, 2000, 2006 and 2012
The number of ship voyages through the Region has increased markedly over the last decade. Each polled ship position for the year is marked by a green dot. Source: Polled ship positions from the Australian Maritime Safety Authority for 2000[138], 2006[139], 2012[140]

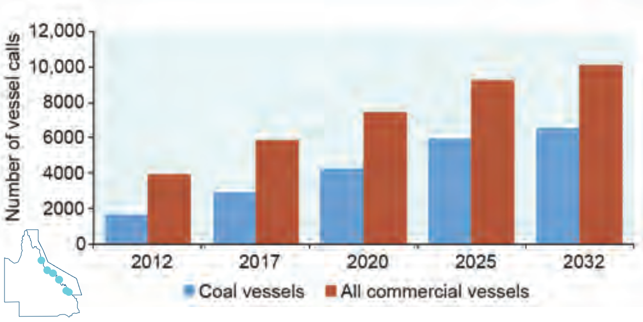

Figure 5.24 Projected shipping increases at major ports, 2012–2032
The category 'all commercial vessels' includes coal carriers, bulk carriers, container carriers, vehicle carriers, general cargo ships, tankers and cruise ships. Fishing, other tourism and recreational vessels are not included. The graph is based on projections of 4.8 per cent annual growth for all commercial vessels and 7.2 per cent annual growth for coal vessels. It is recognised that these projections may be higher than the eventual shipping traffic, depending on variables such as economic conditions. Source: Polglaze, Griffin, Miller and Associates 2012[136]

Cruise ships comprise a minor component of the commercial vessels transiting the Region, representing only 1.5 per cent of the commercial vessel calls to Great Barrier Reef ports in 2011–12.[90] The cruise shipping industry is predicted to grow over coming decades.[141]

Super yachts — large, high-value, luxury vessels — visit the Region. Their numbers are likely to increase into the future underpinned by an increasing number being based in the Asia/Pacific region and by recovering cruising and charter activity across the international market.

Management 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.

The risks of shipping are closely managed.

Shipping traffic is largely confined to a designated shipping area in the Great Barrier Reef Marine Park (Figure 5.23). For ships over 70 metres, and loaded oil tankers, chemical carriers and liquefied gas carriers (irrespective of length), there is compulsory pilotage for the inner route of the Great Barrier Reef (north of about Cairns), Hydrographer's Passage and in and around the Whitsundays.

Mandatory ship reporting improves navigational safety, reduces the risk of shipping incidents and minimises any resulting ship-sourced pollution in the Region. The REEFVTS monitors ship movements in the Region and provides safety information and navigational assistance.

Ship safety is also improved by ship inspections conducted by the Australian Maritime Safety Authority while vessels are in port. Between 2008–09 and 2012–13, the annual inspection rates for ships which visited ports in or adjacent to the Region, were between 58 and 66 per cent.[135] The Australian Maritime Safety Authority's safety regulatory responsibilities were extended in 2013 to include all foreign ships visiting Australian ports regardless of the nature or route of the voyages involved.

There are designated anchorages with a total capacity for 154 ships adjacent to some ports (Figure 5.23). Including swing room, the anchorages cover about 1200 square kilometres. Some have defined anchor points, for example adjacent to the Port of Hay Point.

There are special management arrangements for cruise ships accessing the Marine Park. In addition to requiring a Marine Parks permit, there is a booking system for cruise ships accessing planning areas and designated cruise ship anchorages in both the Cairns and Whitsunday planning areas. Marine park management arrangements for super yachts vary according to their size and whether the visit is for commercial purposes. Their management is guided by the *Queensland Superyacht Strategy 2008–2013*[142] developed by the Queensland Government, in conjunction with industry and other stakeholders.

Amendments to the International Maritime Organisation's *International Convention for the Prevention of Pollution from Ships (MARPOL) Annex V*, which came into force on 1 January 2013, prohibit the discharge of garbage from any vessel into the sea (except under specific circumstances).

In 2013, government agencies with jurisdiction over shipping activities in the north-eastern waters of Australia collaboratively developed the draft *North–East Shipping Management Plan*[143] in preparation for predicted increases in shipping and the associated risks. The draft plan applies to the Great Barrier Reef, the Torres Strait and the Coral Sea (within Australia's Exclusive Economic Zone). It identifies potential risks such as collisions, groundings, release of air emissions and other pollutants, marine pest introduction, wildlife disturbance, altered aesthetic value, and wildlife collisions, as well as impacts on Indigenous, cultural and social values.

5.8.2 Benefits of shipping

Ships that transit the waters of the Great Barrier Reef provide a service to communities adjacent to the Region, transporting export and import cargo as well as visitors to the Region. Australia's export trade carried through the Region (Section 5.5.2) has more than doubled since 2004–05.[144] The economic activity generated by this shipping traffic provides a range of social and economic benefits to catchment communities and beyond.

Shipping provides benefits to catchment communities and the nation.

Cruise shipping and super yachts provide an important platform for the presentation of the Region's values to both national and international visitors.

5.8.3 Impacts of shipping

To date, the impacts of shipping have mainly related to: physical damage and pollution from toxic antifoulant paint as a result of ship groundings; small chemical spills; large and small oil spills; increased noise; vessel strikes on wildlife; vessel-based waste discharge; the introduction of exotic marine species; and marine debris.[94]

Despite the steady increase in shipping activity in the Region, the number of reported ship groundings and collisions has remained relatively stable in recent years (Figure 5.25).[145]

The introduction of additional management arrangements, such as extending the vessel traffic service to the southern boundary of the Region in 2011, has helped reduce the likelihood of these incidents.

Despite an increase in shipping activity, impacts are relatively stable.

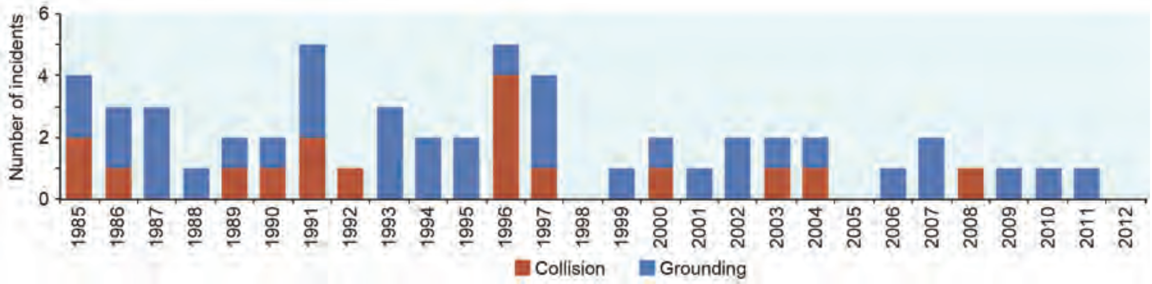

Figure 5.25 Ship groundings and collisions, 1985–2013
Incidents graphed are groundings and collisions reported to the Great Barrier Reef Marine Park Authority involving ships within the World Heritage Area. Note: All collisions identified were between ships and smaller vessels — there were no ship-to-ship collisions reported. Groundings include those within designated port areas. Source: Great Barrier Reef Marine Park Authority[145]

There is also the potential for shipping incidents outside the Region to affect the Region, for example through a disabled vessel or a spill drifting into the area. Such an incident almost occurred in 2012 when the bulk carrier, *ID Integrity*, broke down in the Coral Sea and drifted for five days.

The decline in the age of ships visiting ports in north-east Queensland, from 9.5 years in 2008–09 to 7.8 years in 2012–13 (not including ships on intrastate voyages), is also likely to have improved ship safety in the Region.[135]

Ship grounding sites can take decades to recover.

Ship groundings affect the Region's Indigenous heritage values. For Traditional Owners, the reefs of the Great Barrier Reef have many stories associated with them, and cultural practices and lore linked with such story places can be 'broken' or affected by a grounding. Particular examples include Piper Reef where the *Peacock* ran aground in 1996[146] and the *Doric Chariot* in 2002[147]. Piper Reef is an important story place for its Traditional Owners and these groundings are likely to have affected the cultural heritage of the site. Sudbury Reef, where the *Bunga Teratai Satu* ran aground in 2000[148], is not only a story place but an important cultural place where young men go for a traditional rite of passage[149].

Disturbance from the anchoring of ships is a localised chronic impact which is expected to become more frequent close to ports.[151] For many of the areas where ships anchor, the biodiversity values are likely to be relatively low.[151] The increasing prevalence of ships anchoring off ports is likely to reduce or alter aesthetic values.[151] Other risks include the potential for pest introduction and for the displacement of other users such as recreational visitors and commercial fishers.[151] Unidentified heritage values may also be affected, for example World War II wrecks and shipwrecks, plus Indigenous sites of significance, story places and songlines.

Introduced species can enter the Region on all types and sizes of vessels from yachts to cargo ships (see Section 3.6.3). Species may be transferred on external and internal surfaces of vessel hulls and on equipment which makes contact with the water (for example, propellers, ropes, chains and intake grates). Introduced marine species have been found in ports along the Great Barrier Reef coastline (for example Asian green mussels in the Cairns port), although none have been recorded beyond these ports. The most recent detection was of Asian green mussels on a tug at the Port of Hay Point. There is the potential for introduced species to have regional effects on the ecosystem — the nature of those effects would depend on the species introduced.

There is emerging evidence of additional impacts from ship operations worldwide, for example the leaching of biocides from ships' antifouling coatings[152,153], loss of 'communication space' for marine animals as a result of vessel noise[154] and the disturbance and resuspension of sediment from the wakes of deep-draft vessels.[155] However there is limited information of the effects of these impacts within the Region.

Grounding of *Shen Neng I*, April 2010

The grounding of Shen Neng I caused a large coral plume

In April 2010, a Chinese-registered coal carrier *Shen Neng I* ran aground on Douglas Shoal in the Great Barrier Reef. The vessel was grounded for nine days, severely damaging an estimated 115,000 square metres of reef and causing patchy or moderate damage to much of the rest of the 400,000 square metres that the ship covered during the incident.[150] It is the largest ship grounding scar on the Great Barrier Reef. At best, it is expected the site of impact will take decades to recover.[150] Following the incident there was no immediate access to the resources needed for clean up or restoration of the area and, as at December 2013, none had been undertaken. Antifouling chemicals will be affecting marine life at the site. These chemicals combine with pulverised reef to damage corals and other animals both at the grounding site and surrounding area. The grounding focused attention on the risks of shipping in the southern areas of the Region and, in 2011, the REEFVTS area was extended to its southern boundary.

5.9 Traditional use of marine resources

5.9.1 Current state and trends of traditional use of marine resources

Traditional Owners' connection to sea country within the Region continues to be practised and maintained according to traditional customs and spiritual lore, reflecting ongoing stewardship and custodianship. Traditional use of marine resources is the undertaking of activities as part of Aboriginal and Torres Strait Islander people's customs or traditions, for the purpose of satisfying personal, domestic or communal needs. It includes fishing, collecting (for example, shellfish) and hunting, as well as looking after cultural and heritage sites.

For thousands of years, traditional use of the Region's marine resources has been conducted by Aboriginal people and Torres Strait Islanders. Impacts such as coastal development, habitat degradation, vessel strike on wildlife, marine debris, extractive use and land-based run-off have affected Traditional Owners' use of the marine environment (see Chapter 6). Some Traditional Owners are now working in partnership with government agencies to conserve and protect species and ecosystems critical to the health of people, culture and country.

There is limited information about trends in traditional use of the Region.

Management Traditional Owners with sea country in the Region have traditionally managed the sustainability of their practices as part of maintaining their culture and livelihoods. In the modern context, traditional use must be considered in the overall management of the Region along with many other, often competing, uses and their associated impacts. Traditional Owners from a number of communities have been working collaboratively with managing agencies to manage their sea country through developing and implementing Traditional Use of Marine Resources Agreements. There are currently seven Traditional Use of Marine Resources Agreements (covering 43,221 square kilometres or about 13 per cent of the Region) and one Indigenous Land Use Agreement (Figure 5.26). The area covered by the agreements has more than doubled since the Outlook Report 2009.

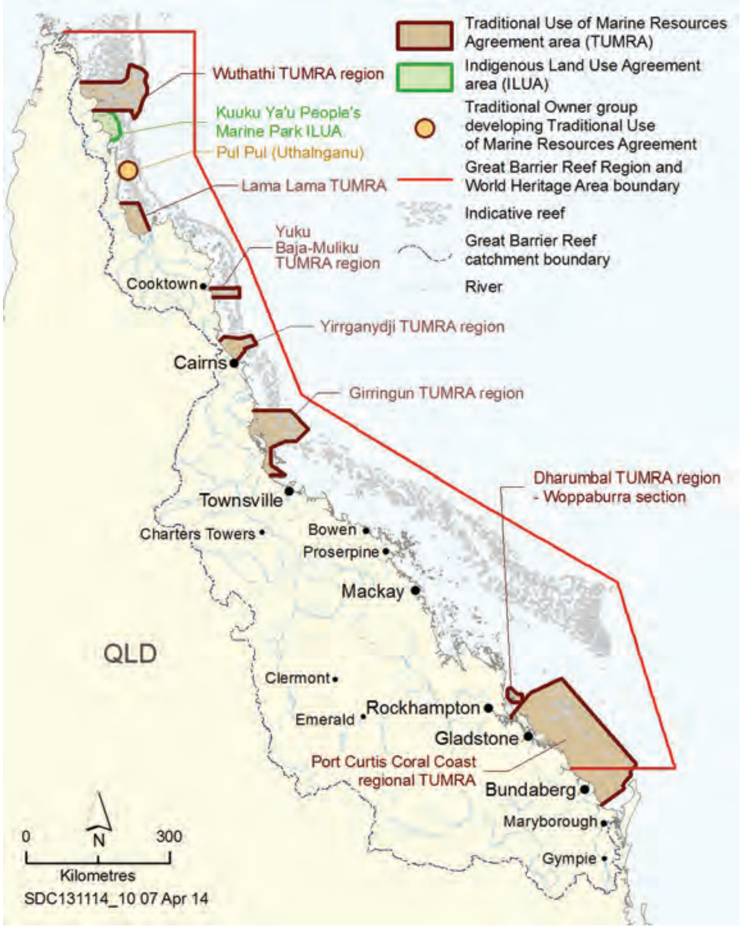

Figure 5.26 Areas of the Great Barrier Reef covered by Traditional Owner agreements, 2014
Some Traditional Owners have formalised their aspirations for sea country through Traditional Use of Marine Resource Agreements and Indigenous Land Use Agreements.

The Great Barrier Reef Marine Park Authority Board membership has included a Traditional Owner representative from the Region for most of the time since late 1996, contributing to setting policy and management direction for the Great Barrier Reef Marine Park.

There are Traditional Owner agreements for about 13 per cent of the Region.

Through their own practices and partnerships with managing agencies, including through the Traditional Use of Marine Resources Agreements, Traditional Owners are working to look after culturally significant species such as dugongs and green turtles. Dedicated Indigenous community compliance liaison officers of the Great Barrier Reef Marine Park Authority work with Traditional Owners and the wider Indigenous community to identify and document concerns about illegal activities on sea country, resulting in improved reporting and detection of illegal activities.

Six Traditional Use of Marine Resources Agreements have an approved Compliance Management Plan, and the seventh is under development. Two have also been developed for areas that do not yet have a Traditional Use of Marine Resources Agreement (Mackay area and Northern Peninsula area).[156]

Traditional use of marine resources continues to provide environmental, social and cultural benefits.

Participants in the Eyes and Ears Incident Reporting program and compliance training for Indigenous community members have included Indigenous rangers, Indigenous and non-Indigenous community members and Traditional Owners of the Great Barrier Reef. More than 300 people have taken part in compliance supporting training packages since 2009. Indigenous rangers contribute to on-ground joint compliance patrols and surveillance within the Region. As a result of the training and education activities there are many more reporting opportunities from geographically isolated locations and the number of reported illegal poaching incidents is expected to increase in the shorter term.[156]

In 2013, the Australian Government announced a dugong and turtle protection plan that will increase Indigenous ranger enforcement and compliance programs to address illegal poaching.

5.9.2 Benefits of traditional use of marine resources

The continuing sea country management and custodianship of the Great Barrier Reef by Aboriginal and Torres Strait Islander Traditional Owners is an important component to the heritage values of the Region.

Many Traditional Owners use marine resources to practise their sustainable 'living maritime culture', provide traditional food for families,[157] and educate younger generations about traditional and cultural rules, protocols and activities in sea country.[158]

Traditions are of high cultural importance, while social sharing during special events that require traditional resources is also critical to maintaining culture.[157] Traditional Owners hold many cultural, economic and spiritual connections to the Region, establishing effective partnerships with them helps protect cultural and heritage values, conserve biodiversity and enhance the resilience of the Great Barrier Reef.

5.9.3 Impacts of traditional use of marine resources

Levels of traditional take are considered sustainable.

Impacts attributable to traditional use of marine resources undertaken according to customs and traditions are considered to have only minor or localised effects. Though the traditional use of marine resources is considered largely sustainable, some culturally important species such as dugongs are facing multiple other threats. In response, some Traditional Owner groups have voluntarily agreed not to hunt dugongs for a period of time.[159,160]

This is distinct from illegal poaching of species of conservation concern undertaken without the customary approval of the relevant Traditional Owners — a focus of compliance effort in the Region.[156]

There have been some recent examples of incompatible use between Traditional Owners' cultural use of marine resources in the sea country areas where they express their native title rights and the activities of tourism operators and other visitors.[14]

Karen and Alison Liddy walking along the eastern side of Marrpa Island (Princess Charlotte Bay) on a cultural heritage trip, 2012

5.10 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:

- economic and social benefits of use
- impacts of use on the Region's values.

5.10.1 Economic and social benefits of use

Outlook Report 2009: Assessment summary

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.

2009 Grade	Current summary and assessment components	Assessment grade and trend				Confidence	
		Very good	Good	Poor	Very poor	Grade	Trend
■	**Economic and social benefits of use:** Use of the Great Barrier Reef continues to contribute to local communities and the national economy. Its economic value has increased over the past five years as has the number of jobs it supports. The number of recreational visits appears to be increasing and declines in tourism visitor numbers until 2011 are now beginning to be reversed. Traditional use helps maintain Traditional Owner connections to their sea country. Some users financially contribute to management.	■ ↔					
■	**Commercial marine tourism:** Tourism continues to make a significant contribution to the presentation, management and economic value of the Great Barrier Reef.	■ ↔				●	●
▨	**Defence activities:** Activities in the Great Barrier Reef continue to directly contribute to the training and operations of Australia's defence services.		▨ ↔			●	●
▨	**Fishing:** Commercial fishing and aquaculture in and adjacent to the Region generate about $160 million per year. Recreational fishing continues to be one of the most popular pastimes in the Region.		▨ ↔			●	●
Not assessed	**Ports:** Ports adjacent to the Region support trade for Queensland industries and communities. Their economic contribution is increasing.	■				●	
■	**Recreation (not including fishing):** The opportunity to enjoy the Region's environment continues to be of social value to Queensland residents, other Australians and international visitors.	■ ↔				◐	◐
■	**Research and educational activities:** A range of academic institutions and government agencies undertake research about the Great Barrier Reef, providing income and employment in regional communities.	■ ↔				●	●
Not assessed	**Shipping:** Shipping through the Region provides a range of social and economic benefits to catchment communities and the nation.	■				●	
■	**Traditional use of marine resources:** Traditional use of marine resources continues to provide environmental, social, economic and cultural benefits to Traditional Owners and their sea country.	■ ↔				○	○

Grading statements

■ **Very good** Use of the Region provides significant economic and social benefit, 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 provides valuable economic and social benefit. The Region is valued by catchment residents, the nation and the world community.

▧ **Poor** There are few and declining economic and social benefits derived from use 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 no economic and social benefit. The Region holds little value for catchment residents, the nation or the world community.

Trend since 2009

↑ Improved
↔ Stable
↓ Deteriorated
— No consistent trend

Confidence

● Adequate high-quality evidence and high level of consensus
◐ Limited evidence or limited consensus
○ Inferred, very limited evidence

5.10.2 Impacts of use on the Region's values

Outlook Report 2009: Assessment summary

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.

2009 Grade	Current summary and assessment components	Assessment grade and trend				Confidence	
		Very low impact	Low impact	High impact	Very high impact	Grade	Trend
🟫	**Impacts of use:** The impacts of different uses of the Great Barrier Reef overlap and are concentrated inshore, particularly next to developed areas. Some uses have only minor and localised effects, for example defence activities, research and educational activities, and traditional use. Cumulative effects of tourism and recreation activities are localised around popular locations. Port activities and their flow-on impacts are generally in areas that are already under pressure from an accumulation of impacts. There are concerns about overfishing of some fish stocks, and the effects of fishing on some species of conservation concern. The survival of non-retained species is not monitored or well understood.			🟧 ↑			
🟨	**Commercial marine tourism:** Marine tourism extends throughout the Great Barrier Reef; its impacts are localised, mainly in a few intensively managed areas.	🟨 ↔				●	●
🟨	**Defence activities:** Most defence activities occur within a limited area. The level of planning and resourcing for defence activities means incidents are rare.	🟨 ↔				●	●
🟧	**Fishing:** Fishing occurs in many parts of the Region, extracting mostly predators and particle feeders. It can result in the entanglement and death of species of conservation concern, reductions of targeted species with implications on the food chain, and impact on Indigenous heritage values. The status of most targeted species and estimates of discarded catch are not well known. Fisheries management continues to improve; more can be done. Illegal fishing remains a concern.			🟧 ↔		◐	◐
Not assessed	**Ports:** Port activities have local adverse impacts, including from dredging and dredge material disposal. Understanding of the effects of dredging and disposal is improving; the cumulative effects are not well understood.			🟧		◐	
🟫	**Recreation (not including fishing):** The impacts of recreation are mainly localised in inshore areas, particularly close to regional centres.		🟫 ↔			◐	◐
🟨	**Research and educational activities:** Research and educational activities are concentrated around research stations; minor, localised effects are likely.	🟨 ↔				◐	◐
Not assessed	**Shipping:** Despite an increase in shipping activity, impacts are relatively stable. Proactive management is addressing emerging risks. Ship grounding sites can take decades to recover.		🟫			●	
🟧	**Traditional use of marine resources:** Traditional hunting, fishing and collecting involves a range of marine species (some of conservation concern) but levels of take are considered sustainable. Poaching is being addressed.	🟨 ↓				◐	◐

Grading statements

🟨 **Very low impact**	🟫 **Low impact**	🟧 **High impact**	🟥 **Very high impact**
Any impacts attributable to use of the Region are minor and localised, with no observable effects on overall ecosystem function or heritage values.	The impacts of use are observable in some locations or on some values, but only to the extent that limited additional intervention would be required for the use to be sustainable.	The impacts of use are obvious in many locations or to many values to the extent that significant additional intervention would be required for the use to be sustainable.	The impacts of use are widespread, to the extent that ecosystem function and heritage values are severely compromised.

Trend since 2009

↑ Increased
↔ Stable
↓ Decreased
— No consistent trend

Confidence

● Adequate high-quality evidence and high level of consensus
◐ Limited evidence or limited consensus
○ Inferred, very limited evidence

5.10.3 Overall summary of commercial and non-commercial use

The economic contribution of the Great Barrier Reef to the Australian economy has increased from approximately $5.4 billion in 2006–07 to $5.6 billion in 2011–12. This is likely to be a small decrease in real terms. There has also been an increase in the full-time positions that are dependent on the Reef from 53,800 in 2006–07 to 69,000 in 2011–12.

Commercial marine tourism continues to be the most significant use of the Reef — both in terms of economic value and employment. In 2011, tourism visitation to the Region was at its lowest point since 1998 most likely due to extreme weather events and the strong Australian dollar. Visitor numbers have since increased in 2012 and 2013.

Commercial and recreational fishing continue to be the most widespread significant extractive use of the Region. Trawl, net, line and pot remain the major commercial fisheries. Some aspects of fishing practices and management arrangements have improved, but more can be done. There is some evidence that, despite ongoing popularity of recreational fishing, recreational catch rates are declining and there have also been some decreases in the commercial catch.

Some fishing activities continue to interact with species of conservation concern and the status of a range of target and bycatch species is poorly understood. There are currently no contemporary estimates of the quantum of bycatch and discard species. Some fishes, sea snakes, sharks, sea cucumbers, skates, rays and associated habitats are at particular risk and, in general, spawning aggregations of inshore fish species are not as protected as those of coral reef fin fish. Illegal activities, particularly associated with illegal fishing and poaching, continue to affect the Region's ecosystem and some of its heritage values. There is evidence of intentional targeting of protected zones by some fishers.

A wide variety of recreational activities occur in the Region, and popular destinations include islands and reefs. Visits to the Region by catchment residents are increasing, likely tied to local population growth and people visiting more frequently. Most impacts from recreational use are localised, however there is potential for cumulative effects over time and in popular areas. Research and educational activities in the Region continue to generate high quality knowledge and learning experiences. These activities are thought to have only localised effects.

Port activities and their flow-on impacts are generally in areas that are already under pressure from an accumulation of impacts. Since the Outlook Report 2009, port activity has increased, as have port development proposals, including dredging and disposal of dredge material. Understanding of the effects on the Region's values of dredging and the disposal and resuspension of dredge material is improving, but many gaps remain. The broader regional and cumulative effects on inshore biodiversity of port activities remain poorly understood. Implementation of national and state ports strategies is expected to critically influence future planning and management of ports in and adjacent to the Region, including environmental protection arrangements.

Ships travelling through the Region have become larger over recent years and their average age is decreasing. Risks associated with projected increases in shipping through the Region are being proactively addressed. Disturbance from the anchoring of ships is likely to become more frequent as the number of ships grows, particularly near ports. Introduction of marine species via shipping continues to be a threat, although there have been only a few recent reported incidents.

Limited information is available on the trends in traditional use of the Region. Traditional Owners continue to work in partnership to help protect cultural and heritage values, conserve biodiversity and enhance the resilience of the Great Barrier Reef. Seven Traditional Use of Marine Resources Agreements and one Indigenous Land Use Agreement are in place.

There are a number of key knowledge gaps in relation to direct use of the Region: reliable estimates of bycatch and discards are currently not available; recreational use, particularly recreational fishing, is not well understood; and advancements in understanding of dredging and the disposal and resuspension of dredge material are necessary to inform near and long-term risk assessments. In addition, there is poor understanding of the community benefits derived from the Region and how population and economic growth and changing societal attitudes affect patterns of use.

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Factors influencing the Region's values

CHAPTER 6

'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*

'an assessment of the factors influencing the current and projected future heritage values...' of the Great Barrier Reef Region, Section 116A(2)(e) of the *Great Barrier Reef Marine Park Regulations 1983*

2014 Summary of assessment

Impact on ecological values	Climate change has already affected the Great Barrier Reef ecosystem. Its effects are compounding the ongoing impacts from land-based run-off and coastal development, particularly loads of sediments and nutrients entering the Region and the modification of supporting coastal habitats. Direct uses contribute to a range of impacts; most are localised. Economic and population growth will likely mean more use of the Region, increasing the likelihood of impacts. The combined influence of the four factors is concentrated in inshore central and southern areas.	🟧 ↑ ↑ High impact, Increased, Increasing
Impact on heritage values	Impacts on the ecosystem are reflected in declines in related heritage values, especially Indigenous heritage, natural heritage and world and national heritage values. Attributes of outstanding universal value relating to natural beauty, natural phenomena, ecological processes, and habitats and species are being affected. For built heritage, the threats from climate change and direct use are the most serious.	🟧 ↑ High impact, Increasing
Impact on economic values	Changes to the Great Barrier Reef ecosystem have serious economic implications for Reef-dependent industries, such as tourism and fishing, and for adjacent communities. Perceptions about the health of the ecosystem affect its attractiveness for tourism and recreation. An increasing coastal population is likely to increase the economic value of direct uses.	🟧 ↑ ↑ High impact, Increased, Increasing
Impact on social values	Declining ecosystem condition, especially inshore adjacent to the developed coast, from the cumulative effects of many factors mean people's attachment to and enjoyment of the Reef may lessen in the future. This may have flow-on effects on Reef-dependent industries. Predicted increasing use may mean more instances of incompatible use.	🟨 ↑ ↑ Low impact, Increased, Increasing

Full assessment summary: see Section 6.7

Factors influencing the Region's values

6.1 Background

Outlook Report 2009: 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. Threats 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 run-off 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.

The Great Barrier Reef Region (the Region) comprises a diverse range of ecosystem and heritage values, described in Chapters 2 to 4. The condition of those values determines the quality of the social and economic benefits the community derives from the Region (such as income, appreciation and enjoyment). A number of factors influence their condition and therefore the quality of the benefits they provide. These influencing factors are themselves affected by broadscale drivers of change (Figure 6.1).

The purpose of this chapter is to examine influences on the Region's values. It begins with an examination of four overarching drivers of change relevant to the Region: economic growth; population growth; technological development; and societal attitudes.

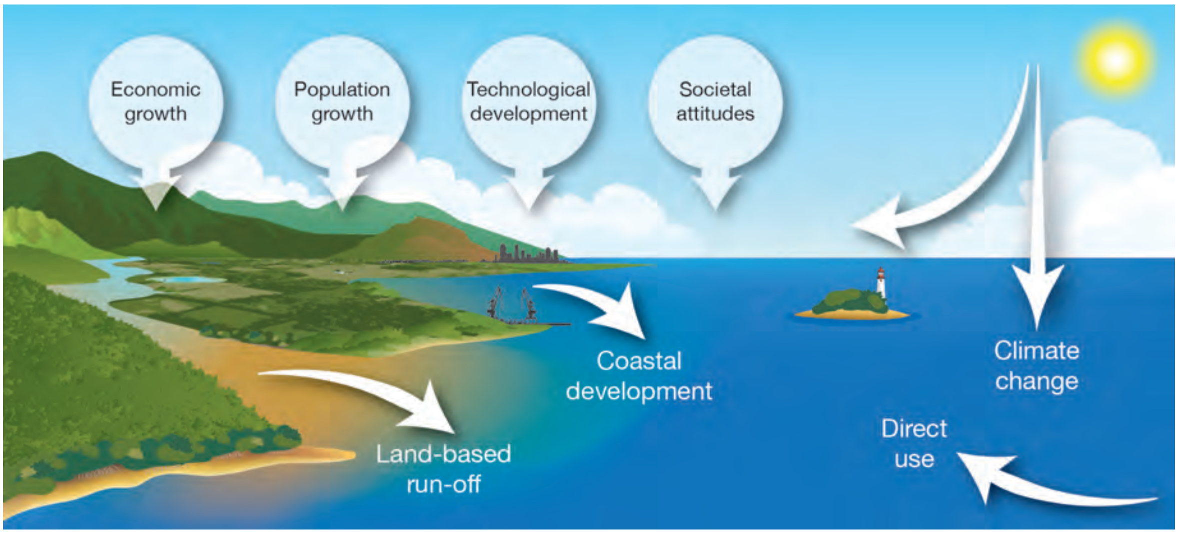


Figure 6.1 Drivers of change and factors influencing the Region's values
The Region's values are influenced by four main factors, climate change, coastal development, land-based run-off and direct use. These are, in turn, affected by broader drivers of change. Climate change has both direct and indirect effects.

This informs assessments of the four main factors directly influencing the Region:

- climate change, having both direct effects on values and indirect effects mediated by other processes
- coastal development
- land-based run-off
- direct use of the Region.

The trends in each influencing factor are described as well as its effect on the ecosystem, heritage values and regional communities. This approach provides a basis for predicting future risks to the Region and its long-term outlook (Chapter 9 and Chapter 10). While direct use occurs within the Region (see Chapter 5), the other three influencing factors are largely external to the Region.

6.2 Drivers of change

Drivers are underlying causes of change in the environment. The drivers examined in this report were identified from the *Australia State of the Environment 2011*[1] and the draft *Strategic Assessment of the Great Barrier Reef Region Report 2013*[2].

Drivers can operate across a range of scales, both in time and space, and they are interlinked, with each one influencing the others. For example, technological developments can play a role in economic growth, population growth and societal attitudes. Similarly, population growth can affect economic growth and societal attitudes.

6.2.1 Economic growth

Queensland has had Australia's highest economic growth for over 20 years.

Queensland's economy is based principally on mining, construction, tourism and agriculture.[3,4] The state's economy has had an average annual growth rate of 4.2 per cent over the last decade (Figure 6.2) and has outpaced the economic growth rate of both the rest of Australia and the Organisation for Economic Co-operation and Development group of nations for the past 20 years.[3] While the effects of the recent global financial crisis were evident in Queensland, particularly in 2009, they were minor in comparison to the rest of the world and the economy has subsequently recovered (Figure 6.2). Over the 35-year period 2015–16 to 2050–51, Queensland's annual economic growth is projected to be between 1.6 and 2.4 per cent.[5]

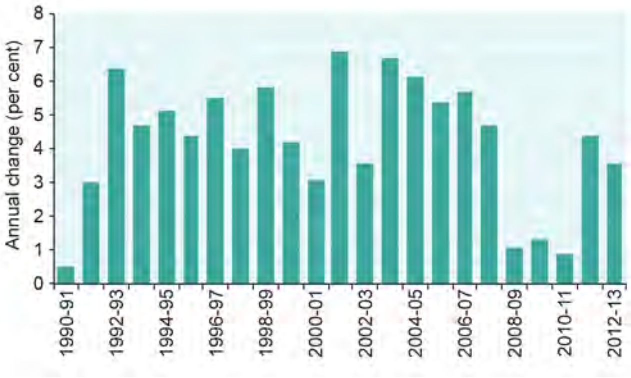


Figure 6.2 Economic growth in Queensland, 1990–91 to 2012–13

The Queensland economy has grown at rates above the national average for the past two decades. The graph shows the annual percentage change in the Queensland gross state product (chain volume measure) for financial years. Source: Australian Bureau of Statistics 2013[6]

The underlying causes of this growth are global events, such as changes in the value of the Australian dollar[7] and the global financial crisis; and domestic growth in the mining industry over the past ten years.

The Australian dollar has appreciated strongly against the American dollar over the past decade and has remained strong since October 2010, when it reached parity with the American dollar.[7] The prolonged high value of the Australian dollar has implications for the national economy, economic activity in the catchment and direct use of the Region, in particular for Reef-dependent industries such as tourism and commercial fishing.

Within the Great Barrier Reef catchment, growth in tourism stabilised between 2007 and 2012, with the total number of visitor nights growing by only 4 per cent.[8] During the same period, international visitor nights declined by around 10 per cent.[8] The decline in international visitors was offset to some extent by growth in the domestic tourism market.[8] Growth in the commercial fishing sector has been less than anticipated. The strong Australian dollar has affected the price of seafood, as Reef-based seafood operators compete with imported product.[9]

Growth in the resources sector has altered land use in the catchment.

Much of Queensland's economic activity takes place in the Great Barrier Reef Region and its catchment, supported by a network of infrastructure (Figure 6.3). The state's strong export trade is dominated by mining and agriculture. About 80 per cent of the world's seaborne metallurgical coal exports are from Queensland[3], shipped through the Great Barrier Reef.

The scale and scope of growth in the resources sector has led to changes in land use within the Great Barrier Reef catchment, particularly in the Fitzroy, Burdekin and Mackay–Whitsunday areas.[10] It has also created unprecedented demands for water, power and new infrastructure including roads, railways and large-scale ports.[10] In November 2013, the Queensland Government released the draft Cape York Regional Plan[11]. The plan identifies areas where economic development activities are prioritised as well as strategic environmental areas where development will be supported if the development outcome is demonstrated to not present a risk of irreversible or widespread impacts to the ecological integrity of the areas. The plan is yet to be finalised.

Over the past six years, there have been fewer catchment residents employed in manufacturing, agriculture, forestry and fishing, and more employed in the mining and minerals sector, particularly in the Gladstone and Isaac local government areas.[3,8]

6.2.2 Population growth

Population growth in the catchment is likely to continue to drive changes in a number of factors influencing the Region's values. These could range from an increase in direct use of the Region to effects on coastal habitats that support the Reef ecosystem.

At the time of writing the Outlook Report 2009, the population of the Region's catchment was 1,115,000. By 30 June 2012, this had increased by about two per cent to 1,165,115. The fastest growing urban centres in the catchment have continued to be Townsville (2.4 per cent in 2011) and Cairns (1.6 per cent in 2011).[12] These cities also had the highest populations — 184,526 and 165,388 respectively in 2012.[13]

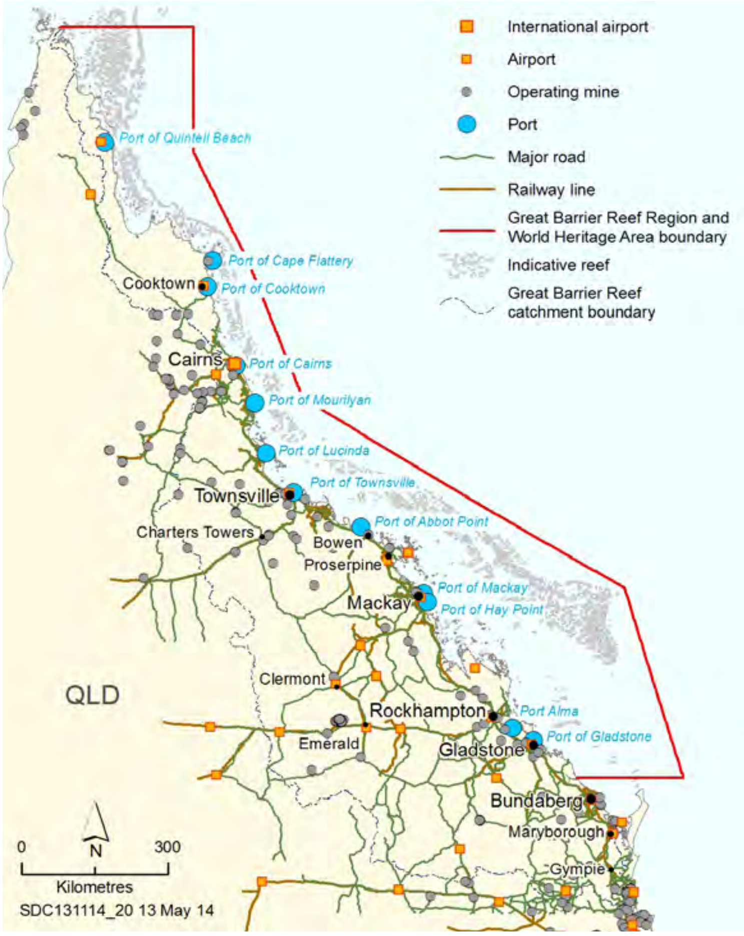
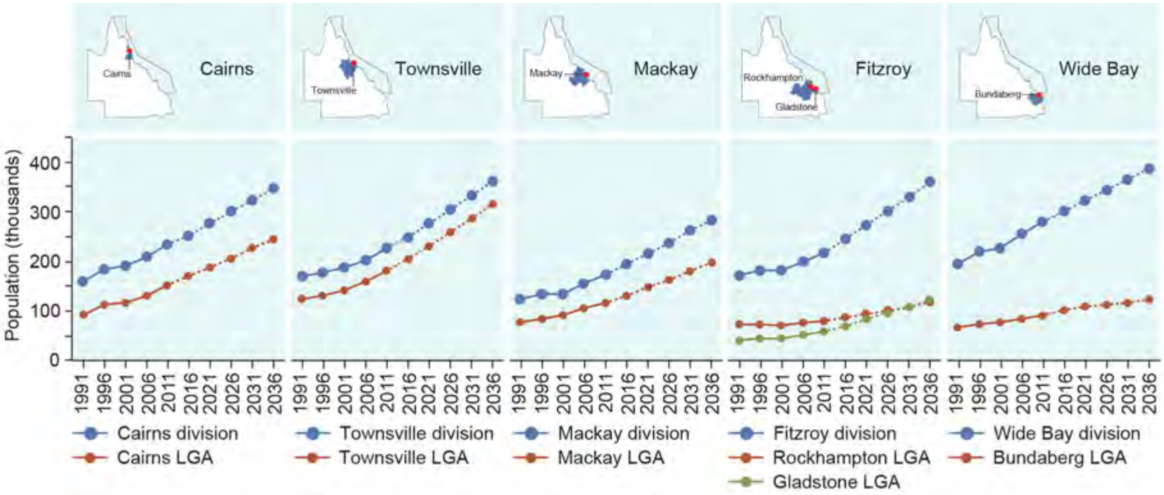


Figure 6.3 Infrastructure in the catchment and beyond
Economic activity in the Region, its catchment and beyond has resulted in a network of supporting infrastructure such as airports, ports, roads and railways.

Over the next 20 years, much of the Great Barrier Reef catchment is forecast to experience annual population growth of 1.6 per cent or higher (Figure 6.4), particularly in the southern half of the catchment.[14] In comparison, the national rate of population growth is projected to slow, but remain above one per cent per annum over the next 20 to 40 years.[15]



Annual population growth is forecast at 1.6 per cent or higher for much of the catchment.

Figure 6.4 Population and forecast increases in the Great Barrier Reef catchment, 1991–2036
Over the last decade, populations have grown steadily along the coast of the Great Barrier Reef. Populations are predicted to continue growing in the statistical divisions (SA4 level) and the main local government areas (LGAs) within the catchment.
Source: Department of Treasury and Trade (Qld) 2014[16,17] and Australian Bureau of Statistics[18] 2013

The fastest population growth will continue to be in the coastal regional centres of the catchment.[19] The Gladstone and Isaac local government areas are expected to expand particularly rapidly, due to increased activity in the resources sector.[17] In contrast, the population of Charters Towers, an inland regional centre, is projected to remain static over the next 25 years.[17]

With an increasing population comes intensification of coastal development in urban areas to accommodate residents and provide supporting services. For example, Townsville's population is projected to grow to 314,000 by 2036.[17] As a result, its number of dwellings is predicted to increase from an estimated 71,000 in 2011 to about 130,500 over the 35 years.[20]

Population growth is likely to increase use of the Region, indicated by increasing vessel ownership in the catchment[21] (see Figure 5.19). In turn, there is likely to be increasing demand for coastal infrastructure to access the Region (for example, roads, marinas and boat ramps) including in previously undeveloped sections of the coast.

New residents moving into coastal areas adjacent to the Region may have less knowledge of its management arrangements than longer term residents, although this is yet to be quantified.

6.2.3 Technological development

Technological development refers to the application of knowledge to create tools to solve specific social, economic or environmental problems. Technological advances have brought major changes to the way people communicate, work, learn, travel and spend leisure time. Technology has changed understanding, management and use of the Region. It can drive both positive and negative changes. Examples of its influence include:

- Global positioning systems allow safer navigation of the Reef and the ability to more reliably locate sites and share locations with others. This technology also provides opportunities for sharing spatial information about the Reef and how it is used, and is providing an increasing number of spatial datasets for management.
- Researchers use state-of-the-art satellite imagery, oceanographic instruments, laboratory equipment, numerical modelling and portable weather stations to better understand, explain and predict changes in Reef condition and the factors that affect it, significantly improving understanding of the Region and contributing to its management.
- The combination of depth sounders and global positioning systems have improved fishers' ability to find fish, accurately relocate previous fishing sites and target deep shoals, wrecks and fish aggregation areas.
- In the catchment, advances in farming technology are reducing the use of fertilisers and pesticides, and reducing soil disturbance and erosion. This is helping to slow and reverse negative trends in Reef water quality with economic benefits for farmers.[22,23]
- Continuing advances in communication technology have resulted in increased education, awareness and involvement of the public in environmental monitoring of the Region, for example through use of the Eye on the Reef smart phone application.

Technology has changed understanding, management and use of the Region.

Into the future, technological developments which better guide and monitor shipping traffic, enhance visitor experiences, reduce carbon emissions, monitor Reef use, spatially represent values and impacts, and contribute to the collective understanding of the Reef, will enable the environment to be better protected and managed. Changing vessel and navigational technology is likely to change the spatial patterns of fishing, tourism and recreational use, including allowing vessels to safely reach new, more distant locations and better focus their use on preferred locations.

6.2.4 Societal attitudes

Societal attitudes operate at international, national and local scales, and are shaped by cultural and social norms, institutional arrangements, economic imperatives and politics. They may be strongly influenced by external sources, particularly the mass media.[24] Societal attitudes influence individual actions and community outcomes, for example the potential for an individual, group or community to take action to help conserve natural assets such as the Great Barrier Reef.

Societal attitudes about the Reef have changed dramatically through time and will continue to do so into the future. Today, most Australians, even those who have not visited the Region, feel proud that the Great Barrier Reef is a world heritage area; many believe the Reef is part of their Australian identity and feel a strong sense of responsibility to protect it.[25]

For thousands of years, societal attitudes about the Reef were those held by the Traditional Owner groups whose customary estates include sea country within the Region. Their culture and lore was reflected in ongoing stewardship and custodianship of the Reef environment. Traditional Owners continue to maintain a close and dynamic connection to their sea country, which integrates nature, heritage and culture.

The attitudes of early European explorers were principally shaped by their anxiety about being shipwrecked, due to the sheer size and complexity of the coral reef system. By the late 1800s, non-Indigenous Australians saw the Reef as a bountiful resource to exploit, for example through dugong and turtle harvesting, pearling and commercial fishing. It was not until the early part of the twentieth century that they also began to explore its natural wonders in earnest, through science, recreation and tourism. This appreciation of the Reef flourished during the 1940s, 1950s and 1960s, and continues today.[26]

Societal attitudes influence people's attitudes and actions in relation to the Reef.

By the mid-1960s, Australians were beginning to express concerns about the future of the Great Barrier Reef, particularly with respect to outbreaks of crown-of-thorns starfish and the possibility of drilling for oil.[26] Growing public affinity for the Reef and a sense of responsibility for its future led to proclamation of the *Great Barrier Reef Marine Park Act 1975* and subsequent progressive protection of the Great Barrier Reef as a marine park. Members of the community now take an active interest in the Reef and its protection, for example through expressing their opinion on major changes to management, such as zoning arrangements or permit decisions. Strong community concern around dredging and dredge material disposal was expressed during 2013 and early 2014. By January 2014, there was a combined total of over 1.5 million signatures on related petitions.[27,28,29]

Governance arrangements — a reflection of societal attitudes — play a major role in shaping the condition of the Region's ecosystem and heritage values, for example through legislation, non-regulatory incentives for behaviour change, and international agreements and conventions (such as the World Heritage Convention and trade agreements).

Education and awareness of the Reef and its values influence societal attitudes. Stewardship actions driven by community and industry are critically important in modelling both changed attitudes and actions that people can take to support management initiatives and maintain and enhance the Region's values. Education and stewardship are central tenets of many management programs for the Region. The growing interest in stewardship programs reflects shifts in thinking towards ecologically sustainable development, human wellbeing and a healthy, vibrant Great Barrier Reef.

Inspired to help monitor the Reef, tourism staff learn how to perform reef health surveys

6.3 Climate change

Climate change directly affects the Region through physical and chemical impacts on the ecosystem and heritage values. It also has indirect effects on these values by changing the way people interact with the Region and by affecting the other factors (such as land-based run-off) that influence the Region's values.

The climate is changing, with significant implications for the Region.

The rate and extent of increases in global greenhouse gas concentrations drive climate change. Increased concentrations of greenhouse gases (particularly carbon dioxide) in the atmosphere result in more heat being trapped, increasing the Earth's temperature. Increasing carbon dioxide levels in the atmosphere also cause ocean acidification, a gradual reduction in the pH of seawater.[30] Both these consequences (global warming and ocean acidification) are considered together in this assessment under the influencing factor 'climate change'.

6.3.1 Trends in climate change

The 2013 Working Group I contribution to the Intergovernmental Panel on Climate Change (IPCC) fifth assessment report concludes that *'warming of the climate system is unequivocal and, since the 1950s, many of the observed changes are unprecedented over several millennia. The atmosphere and oceans have warmed, the amounts of snow and ice have diminished, sea level has risen, and the concentrations of greenhouse gases have increased'.*[31]

A number of climate change variables are already changing and, based on a combination of global and regional climate models and observations, are projected to alter substantially in the Great Barrier Reef over the next 50 years.[31,32,33,34] It is likely that climate change will drive global changes in prominent weather characteristics and events such as cyclones, heavy rainfall, droughts, air temperature and prevailing winds.[31,35,36] For example, while cyclones and other extreme weather events are a natural part of the weather cycle in tropical areas (see Section 3.2.2), the global climate system is now warmer and moister than it was 50 years ago, and this is increasing the chances of intense weather events.[37,38]

Concentrations of carbon dioxide have increased by 40 per cent since 1750, primarily from fossil fuel emissions and secondarily as a result of changes in land use.[39,40] The mean rates of increase in atmospheric concentrations of carbon dioxide, methane and nitrous oxide over the past century are unprecedented in the last 22,000 years, and are now at concentrations unprecedented in at least the last 800,000 years.[40] Over the last five years, global carbon dioxide levels have continued to increase at a rate similar to that of the last 50 years, increasing from 386 to 397 parts per million from July 2008 to December 2013 (Figure 6.5).[41]

Four representative concentration pathways (RCPs) for atmospheric greenhouse gases were developed for use in the fifth assessment report of the Intergovernmental Panel on Climate Change. Of these, the RCP 4.5 represents a 'radiative forcing is stabilised before 2100' scenario and RCP 8.5 represents a 'radiative forcing is stabilised after 2100' (very high emissions) scenario.[31,42] Projections indicate carbon dioxide levels of around 435 (RCP 4.5) to 758 (RCP 8.5) parts per million by 2030, and around 531 (RCP 4.5) and 758 (RCP 8.5) by 2080.[43]

More than half the observed increase of 0.6 degrees Celsius in global mean **surface (air) temperature** from 1951 to 2010 is very likely due to anthropogenic greenhouse gas emissions; it is likely that anthropogenic influence has made a substantial contribution to surface temperature increases over Australia.[44] Globally, each of the past three decades has been significantly warmer than all the previous decades in the instrumental record and the first decade of the twenty-first century has been the warmest.[39] Regionally, mean temperatures are increasing. Projections based on RCP 4.5 and RCP 8.5 suggest temperature will rise by around one to two degrees Celsius by 2030, and by one to over three degrees by 2080.[34,44]

The ocean is already getting warmer and pH is decreasing.

Sea surface temperatures in north-eastern Australia have warmed, on average, by 0.12 degrees Celsius per decade since 1950.[34] In the Coral Sea over the past century, 15 of the 20 warmest years have been in the past 20 years (see Section 3.2.6).[45] Following on from record sea surface temperatures in October to December 2010 for many areas of tropical Australia[45,46], records were set again in the summer of 2012–13 when the hottest sea surface temperatures for the Australian region were recorded.[37]

Strong ocean warming is projected for tropical regions.[30] Whatever climate scenario is used, it is predicted that by 2035 the average sea surface temperature will be warmer than any previously recorded, and by 2100 average sea temperatures off north-eastern Australia could be about 2.5 degrees Celsius warmer than the present average.[32,34,38,45]

Global average **sea level** has risen by 0.18 centimetres per year from 1961 to 2003.[47] The total rise from 1901 to 2010 was 19 centimetres.[48] Around Australia, and in the Great Barrier Reef, the fastest rates of sea level rise are in the north (Figure 6.6 and see Section 3.2.5).[49,50] The frequency of extreme sea level events (storm-driven waves and surge) increased by a factor of about three during the twentieth century.[50] Projections based on RCP 4.5 and RCP 8.5 are for global sea level to rise by around 26 to 29 centimetres by 2030, and by around 47 to 62 centimetres by 2080.[48]

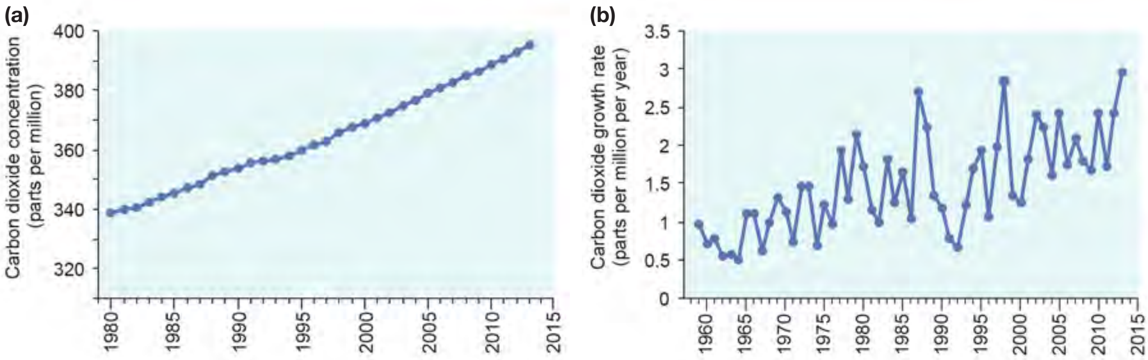


Figure 6.5 Changes in global atmospheric carbon dioxide concentrations
Global carbon dioxide concentrations in the atmosphere have been rising. Both (a) global carbon dioxide concentrations (1980–2013) and (b) the annual mean carbon dioxide growth rate (1959–2013) are rising. Trends shown are based on globally averaged marine surface data. Source: Dlugokencky and Tans 2014[41]

Ocean uptake of carbon dioxide will increase **ocean acidification**, continuing the observed trends of past decades and reducing pH within the Region's waters (see Section 3.3.2).[30,51] Global ocean surface pH is currently 8.1 and there is high confidence that it has decreased by 0.1 since 1750.[30] Projections based on RCP 4.5 and RCP 8.5 are for further reductions in pH of around 0.05 to 0.2 by 2030, and around 0.05 to 0.3 by 2080.[40]

Currents There is increasing evidence of changes in the East Australian Current adjacent to the Region's southern coast (see Section 3.2.1). Its flow is expected to increase off south-east Australia with a compensating decrease off north-east Australia.[52] There is little information about the Hiri Current, another of the Region's prominent currents.

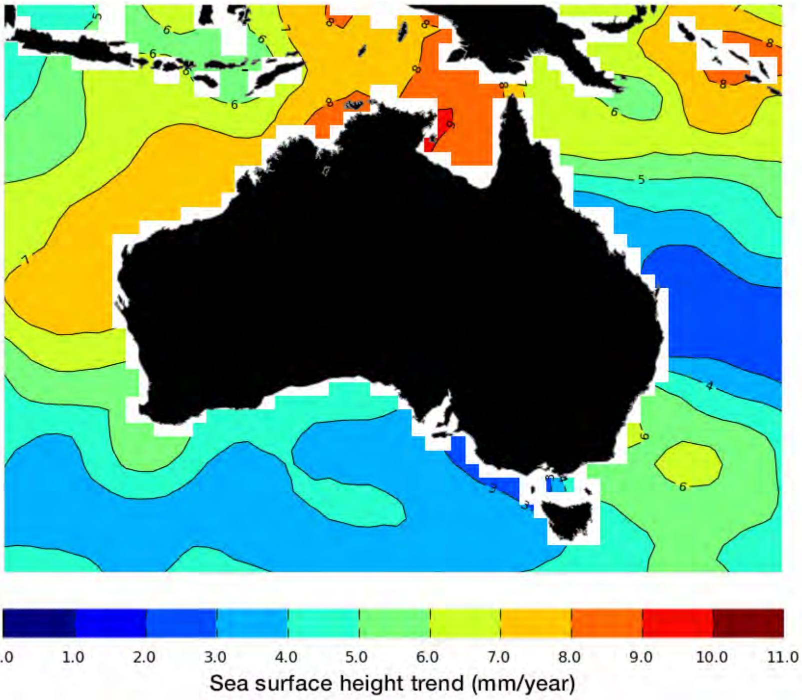


Figure 6.6 Rates of sea level rise in Australia, 1993–2013
Rates of sea level rise are highest in northern Australia. The map shows the rate of sea surface height rise measured by satellite observations. Note: satellite observations have had the seasonal signal removed and small corrections applied for changes in atmospheric pressure. Source: Australian Baseline Sea Level Monitoring Project and CSIRO, map adapted from Bureau of Meteorology 2014[49]

Both tropical **cyclones** and east coast lows can produce extreme wind speeds and heavy rainfall.[53] Over the last decade, particularly between 2005 and 2012, there have been a number of severe tropical cyclones in the Region (see Section 3.2.2). Most of the Region has been exposed to severe cyclonic winds during that time; with the area between Cairns and Townsville particularly affected (Figure 6.7). There is low confidence in determining changes in cyclones over a century scale[39], but the frequency of eastern Australian land-falling cyclones has possibly declined since the late nineteenth century.[39,53] The frequency of tropical cyclones is likely to decrease or remain unchanged, though there is a possible trend towards more intense storms[39,54]; however, confidence is low in regional projections[55,56]. An increase in intensity would increase the proportion of severe tropical cyclones (categories three, four and five). A small poleward shift in storm tracks is likely.[55]

North-east tropical rainfall is concentrated during the summer and is variable from year to year. Indicators of flood events, dating back to late seventeenth century show that wet and dry extremes have become more frequent since the late nineteenth century.[60] Between late 2010 and early 2011, one of the strongest La Niña events on record since the late 1800s was observed[61] resulting in record high rainfall and widespread flooding in many areas (see Section 3.2.3).

The global average sea level has risen about 19 centimetres since 1901

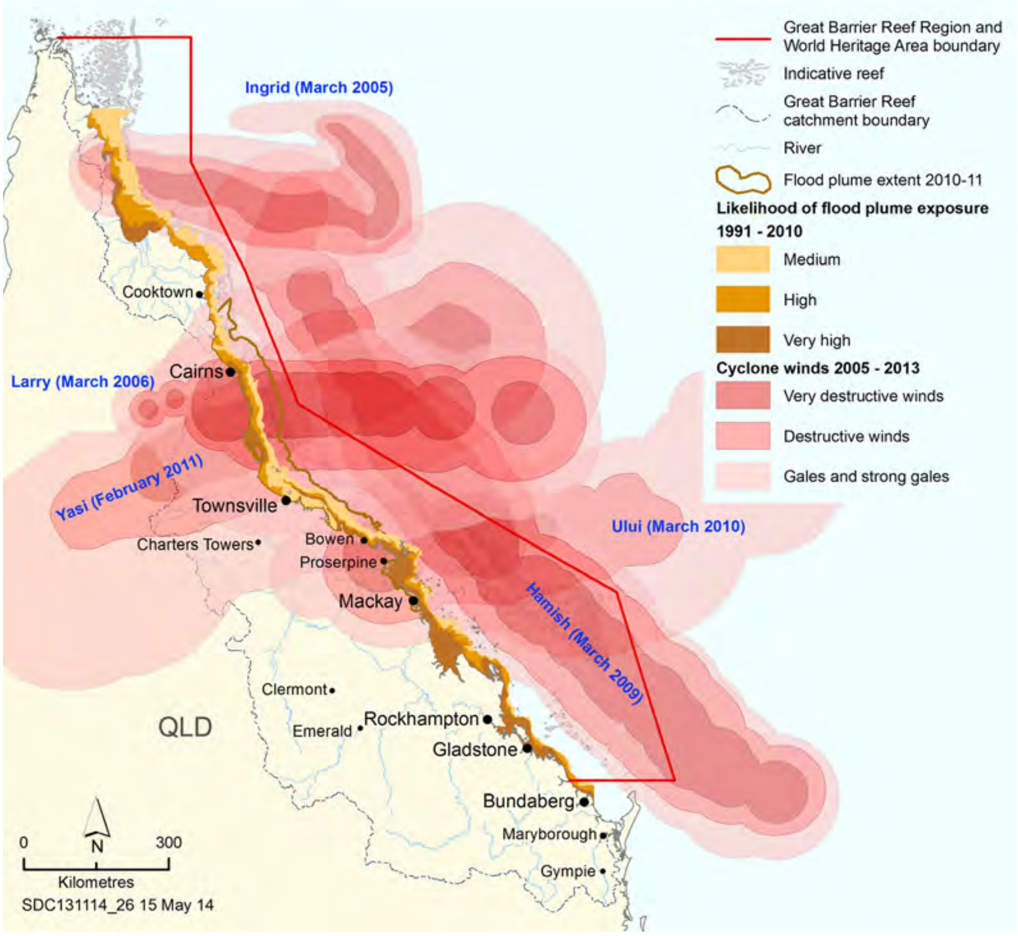


Figure 6.7 Cyclonic wind (2005–2013) and flood plume (1991–2010) exposure

The cluster of severe cyclones and flood events in recent years has significantly affected the condition of many Great Barrier Reef habitats and species. Winds shown are those associated with category 4 and 5 cyclones. The likelihood of flood plume exposure (brown areas) is a cumulative assessment of multiple flood plumes based on remotely sensed conditions at the sea surface. The flood plume extent for 2010–11 (brown line) indicates the distribution of the flood plume as a result of the extreme weather events experienced over that summer. Source: Bureau of Meteorology 2013[57] (cyclones) and Devlin *et al.* 2011[58] (flood plume exposure)

Across Australia, heavy **rainfall events** and associated flooding are likely to become more frequent as air temperatures increase.[37] In northern Australia average monsoon rainfall may increase.[55] There will be a tendency for more large freshwater inflows to the marine environment. Rainfall is likely to become more variable, and the direction and magnitude of change in eastern and northern Australia remains a key uncertainty.[55]

The El Niño–Southern Oscillation is the most important driver of natural **climate variability** in the Region and is likely to remain so.[55,62,63,64] Extreme El Niño events occurred during 1982–83 and 1997–98 with widespread coral bleaching observed.[64,65,66,67] There is no consensus on observed long-term changes in the El Niño–Southern Oscillation, and low confidence in projected change in its variability.[55] Extreme El Niño occurrences are projected to increase.[38]

6.3.2 Vulnerability of the ecosystem to climate change

Current and future climate change related threats to the Region's ecosystem include sea temperature increases, altered ocean currents, changed weather patterns, ocean acidification and sea level rise. Potential effects for populations of species and groups of species and habitats are considered in many recent scientific studies.[34,68,69,70,71,72] The effects, both individually and combined, are likely to have far-reaching consequences for the Region's ecosystem and its outstanding universal value as a world heritage area.

The 2013 water quality scientific consensus statement[73] concluded that '*key Great Barrier Reef ecosystems are showing declining trends in condition due to continuing poor water quality, cumulative impacts of climate change and increasing intensity of extreme events*'.

For most ecosystem values, knowledge regarding the range and extent of impacts is limited, but growing steadily. However, the projected vulnerability of a number of the Region's habitats and species indicates not all components are affected equally.[72] Corals and seabirds are considered to be some of the most vulnerable species[68,71,72,74] — both key attributes of the area's outstanding universal value.

Continued **increases in air and sea temperature** pose significant risks over the coming decades across the whole Region, influencing a range of physical, chemical and biological conditions and processes and, hence, many different habitats and species.[75] Seabird nesting and shorebird roosting sites are at risk and increasing sea temperatures are affecting food availability for offshore and pelagic-foraging seabirds.[76,77] Sea temperature extremes considered to be caused by climate change (see Section 3.2.6) have already had some serious effects, including mass coral bleaching in 1998 and 2002[78,79] and reduced growth rates in massive corals across the Region.[68,79,80,81,82]

Rising sea temperatures will damage coral and affect other animals.

Under a scenario where radiative forcing stabilises before 2100 (RCP 4.5)[42], bleaching conditions are predicted to start to occur twice a decade in 2018 for most of the Great Barrier Reef, with these conditions beginning slightly later (between 2033 and 2043) in the inshore southern Reef.[83] In the same scenario, annual bleaching conditions are predicted to start occurring in the period from 2052 to 2067 with earlier annual bleaching conditions (2047) in the southern inshore Reef and later (after 2067) in some parts on the central Reef.[83]

Pelagic-foraging seabirds are highly vulnerable to **changes in ocean currents**.[74] There is evidence that climate change has driven the ranges of Australian seabirds further south, reduced breeding success and altered breeding timing for some species.[74] Altered ocean circulation patterns may also affect the transport of eggs and larvae of many animals within and among Great Barrier Reef habitats and influence species distributions. The movement of marine turtle hatchlings away from nesting beaches may be affected[84], as may coral larval dispersal. Projected increases in ocean stratification — the vertical layers in the water column — are predicted to affect the supply of nutrients and oxygen into deeper pelagic and seafloor ecosystems with implications for the organisms that live there.[51]

Changes to ocean currents may disrupt transport of nutrients and larvae.

As the climate changes, the capacity of hard corals to grow and reproduce will be increasingly compromised with flow-on effects on other species dependent on coral reefs. Reef-building corals are highly vulnerable to increasing sea temperature, ocean acidification and increased intensity of cyclonic activity and other weather **pattern changes**. For example, modelling predicts severe cyclones have been responsible for about half of the total coral cover loss in the Great Barrier Reef since 1985[68] due, in part, to the associated high intensity waves (Figure 6.8). In another study, for places where declines in live coral cover were observed, around a third of the decline was attributed to the effects of storms.[85] Abnormally high rainfall and associated flood events can have negative effects such as low salinity bleaching and mortality in corals[86] or widespread damage to seagrass meadows[87,88,89,90].

Weather pattern shifts may increase frequency and distribution of disturbance.

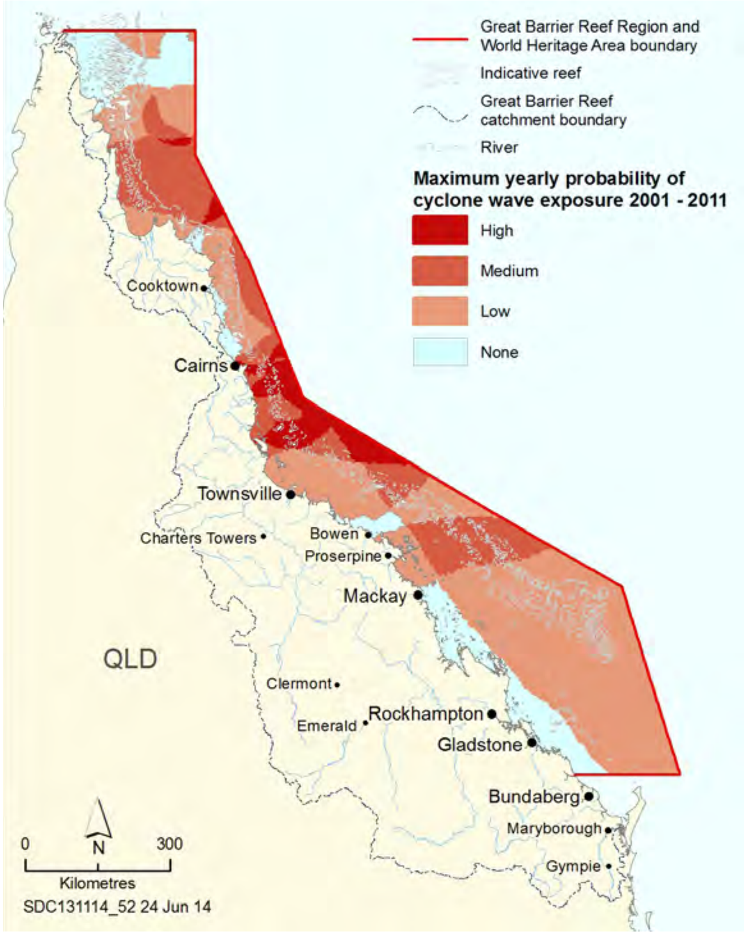


Figure 6.8 Cyclone wave exposure, 2001–2011
For the Region, a significant wave height of four metres is likely to damage many species. The map presents the probability that four metre significant wave heights formed for at least an hour in a given year for the period from the summer of 2000–01 to the summer of 2010–11.[59] Gradings are scaled based on a maximum yearly probability of 31.7 per cent: low (less than 11 per cent chance), medium (11 to 22 per cent chance) and high (22 to 31.7 per cent chance). Source: Maynard et al. 2014[59]

Tropical habitats such as coral reefs, seagrass meadows and islands have a natural resilience to physical disturbances from weather events such as storms and cyclones, intense rainfall and heatwaves. However, climate change induced shifts in weather patterns that affect the frequency, intensity or distribution of disturbance events will have important implications for the Region.[45,68,91,92,93] Additionally, it is thought the cumulative effect of multiple severe weather events and anthropogenic threats over the past decade may reduce the Reef's resilience, in particular its ability to recover.[85,93,94,95,96,97] Changes in wind patterns and intensity may have implications for the resuspension of sediments in the Region, including those delivered from the catchment and those disposed of during dredging activities.

It is predicted that **ocean acidification** could ultimately affect most marine life through habitat destruction or modification, food web deterioration and disruption of physiological processes.[98] In addition, the effects of global warming and ocean acidification may magnify each other[99] and may not occur uniformly from place to place and over time.[100] Even relatively small decreases in ocean pH reduce the capacity of corals to build skeletons, which in turn reduces their capacity to create habitat for reef biodiversity in general.[99,101] Additionally, if coral skeletons are weakened they may have lowered capacity to resist and recover from physical damage caused by cyclones.[102] Reef development is thought to cease at pH 7.8.[103] Field observations at natural carbon dioxide seeps have found more acidic oceanic conditions do not necessarily affect coral cover but reduce species diversity and structural complexity.[103] Decreasing pH is likely to reduce the capacity of coralline algae, a species vital to reef building, to cement reef debris into solid limestone.[70,104] It is also likely to affect coral recruitment and establishment.[70] Other biota such as phytoplankton, foraminifera and molluscs are also at risk.[104,105,106] The sensory systems, behaviours, and larval development and survival of a number of reef fish species including coral trout have been shown to be sensitive to increased temperature and acidity.[107] Some seagrass and non-calcifying macroalgae may benefit from future ocean acidification.[103,108,109]

Ocean acidification threatens physiological processes for a wide range of organisms.

Rises in sea level are significant for the Great Barrier Reef ecosystem as some habitats are shallow and strongly influenced by sea level. In particular, because much of the land adjacent to the Great Barrier Reef is low lying, small changes in sea level will mean increased erosion and land inundation, causing significant changes in tidal habitats such as mangroves, and saltwater intrusion into low-lying freshwater habitats.[110,111] Brackish saltmarsh habitats are being displaced by mangroves.[112] Turtle and seabird nesting beaches, including on islands, are particularly vulnerable to rising sea levels, which exacerbate beach erosion[113] and inundate nests[114].

As well as its direct effects on the Region’s ecosystem, climate change will also have indirect effects on the Reef’s resilience through amplifying the effects of other influencing factors such as coastal development and land-based run-off. For example, flood events carry pulses of nutrients, sediments, pesticides and other pollutants from the catchment, which have significant effects on inshore Great Barrier Reef habitats and species.[115] Extreme weather events such as those in 2010–11 result in large amounts of marine debris washing or blowing into the Region from the catchment.[116,117]

Additionally, engineering solutions to improve the resistance of coastal assets to rising sea levels and increased storm intensities may interfere with the connectivity of coastal and marine systems or cause damage or loss of coastal habitats.[118,119,120]

6.3.3 Vulnerability of heritage values to climate change

Section 6.3.2 has demonstrated the very high vulnerability of the Region’s ecosystem to climate change. The vulnerability flows through to dependent heritage values. The Region’s world and national heritage values, including those attributes relating to Traditional Owners’ interaction with the natural environment, are underpinned by the ecosystem and directly affected by changes to it. Indigenous heritage values are particularly vulnerable because, as described in Chapter 4, the natural environment is fundamental to Traditional Owner connections to their land and sea country. The cultural landscape of the Region, and climate change threats to it, cannot be fully understood without recognising this.

Many aspects of Indigenous heritage such as cultural practices, sacred sites, sites of particular significance, stories, songlines, totems, language, technology, tools and archaeology will be affected by global warming and ocean acidification. Some impacts will come as a result of ecosystem effects, while others will occur directly. Historic heritage places and artefacts are at risk too, along with social, aesthetic and scientific values.

Heritage sites on beaches and in the intertidal zone are likely to be particularly vulnerable to sea level rise. Traditional Owners have observed impacts on the fish traps in Girringun country (Cardwell) from **rising sea levels.**[121] Once culturally significant sites are affected, stories and songlines are compromised and customary practice may have to be changed.

As **weather patterns** change, the impacts on the Region’s heritage values of storms, cyclones, high rainfall events, heatwaves and droughts may increase. Severe weather events can lead to adjustments in traditional use of marine resources, for example moratoria on collecting certain species.[122,123] In turn, this can mean places important for cultural tradition may not be visited, or stories and songlines might not be practiced or passed down to younger generations, because those aspects are directly related to fishing, collecting or hunting activities.

Altered weather patterns and sea level rise increase risks to built structures.

Cyclones change land and seascapes and can affect places of heritage significance including Indigenous[124] and historic heritage structures and sites, both those on land (such as lightstations) and submerged (such as historic shipwrecks). An example is cyclone Yasi’s exacerbation of the deterioration of the wreck of the SS *Yongala* (see Section 8.5.3).[125] Built heritage such as lightstations are at risk of physical damage from infrequent but intense weather events like cyclones, but may also be degraded by more chronic subtle changes such as wind pattern shifts that accelerate weathering or other deterioration.[126]

Indigenous and historic heritage values such as those on Low Island are vulnerable to changes in weather patterns

If altered weather patterns result in increased **marine debris** (Section 6.3.2) in the water and on the Region's beaches, aesthetic values will be diminished.[127] Aesthetic value could also be affected if island and other terrestrial habitats change as a result of a shifted climate.[128]

While the spatial locations of important scientific discoveries are unalterable, the habitats and species fundamental to that history are not. In many instances the relevant ecosystem values, and therefore the scientific heritage values associated with them, are likely to become significantly degraded through the effects of global warming and ocean acidification.

6.3.4 Implications of climate change for regional communities

Many Australians are concerned about the Great Barrier Reef being damaged or threatened by climate change.[25,129] Climate change is likely to affect the way people interact with the Region and the social and economic benefits they derive from it. For example, foreshores and coastal infrastructure such as ports[130], and the benefits communities derive from them, will be influenced by climate change impacts on the catchment and the Region. Climate change will also have implications for health and disaster risk management.[131,132,133,134]

Climate change effects on the ecosystem are expected to have major economic consequences for Reef-dependent industries.

The effects of climate change on coral reef ecosystems are predicted to be widespread and irreversible.[135] Therefore, climate change poses one of the greatest risks to the future economic value of Reef-dependent industries such as tourism, fishing and recreation. While the implications of climate change for the economic value of Reef-dependent industries are numerous and there is an improved understanding of these[91], they remain difficult to accurately quantify.[136]

The tourism industry is very concerned about the impacts of climate change on its businesses and livelihoods, including through degradation of reef sites, poor recovery of bleached sites as a result of other stresses, and a loss of marketing appeal as a high-quality reef destination.[137] A healthy and resilient Reef is fundamental to the success of many tourism operations and deteriorating Reef conditions may reduce visitor satisfaction. In a 2013 survey of visitors to the Region the most important motivations for their visit were those relating to the state of the ecosystem — for example, clarity of water, iconic species, healthy reef fish and healthy coral reefs (see Section 5.2.2).[127]

Deteriorating Reef condition may reduce visitor satisfaction with their Reef experiences.

It is likely fishing activities will also be highly sensitive to climate change, including as a result of projected changes in fish abundance, survivorship[138,139,140], size and distribution, disruptions to shallow-water nurseries and loss of coral reef habitats, as well as changes in cyclone and storm activity.[72,141,142]

Extreme weather events may provide a window into the future for predicting impacts of climate change on coastal communities, especially the flow-on effects of major ecosystem disturbances. In 2010–11 the Queensland coastline experienced high levels of flooding and was exposed to several cyclones, resulting in widespread damage to road and rail networks, and port and airport closures.[143] Reef-based tourism operators were disadvantaged by public perceptions that the whole of the Great Barrier Reef was damaged by cyclone Yasi.[143] Local fishers experienced difficulties going fishing and in getting their produce to market. Ongoing poor weather and damage to property and infrastructure in the Cassowary Coast left local fishers feeling uncertain about their capacity to fully recover, as they had only just recovered from cyclone Larry in 2006.[143]

The vulnerability of commercial fishers and tourism operators to climate change will depend on their exposure and sensitivity to the associated impacts, as well as the ability of the individuals or operators to anticipate and adapt to change.[93] Although severe weather events such as floods and higher intensity cyclones may interrupt Reef-based businesses and decrease visitor satisfaction, the level of identity with, and attachment to, the Great Barrier Reef by Reef-based industry and community members is likely to remain high.[144,145]

Damage to foreshores and coastal infrastructure affects people's use of the Region

6.4 Coastal development

Aboriginal people have lived along the coast of the Great Barrier Reef for over 40,000 years. Europeans first settled the area in the 1850s and since that time an increasing number of people have lived and earned their livelihoods there, often based around the natural resources of the Great Barrier Reef.

For the purposes of this report, the term coastal development includes all development activities within the Great Barrier Reef catchment. Uses of the catchment relevant to the Region are agriculture, mining, urban and industrial development, port activities and island development. The influence of coastal development on the Region arises from both the legacy of past development actions, such as broadscale clearing of catchment habitats for agriculture, and current and future actions, such as smaller scale clearing and reclamation for urban and industrial development.

Since the Outlook Report 2009, a large body of work has been synthesised to better understand the influence of modifications to coastal ecosystems on the Region's values (see Section 3.5).

Diffuse source pollutants from the catchment, principally as a result of agricultural activity, and their influence on water quality entering the Great Barrier Reef is discussed in the land-based run-off section (Section 6.5).

6.4.1 Trends in coastal development

The overall extent of agricultural land use has remained stable in recent years.

Agriculture The majority of land in the catchment is used for grazing, cropping, dairy and horticulture, with more than 80 per cent of the Great Barrier Reef catchment supporting some form of agriculture. Cattle grazing is the most extensive land use, occurring in more than 74 per cent of the catchment (Figure 6.9).[10,146] It is particularly extensive in the larger, drier catchments — the Fitzroy and Burdekin — but is a significant portion of most catchments, even the Wet Tropics.[10,146] Smaller coastal catchments support more intensive agricultural uses such as cropping (mostly sugarcane). They also support forestry activities, which are undertaken in about five per cent of the catchment.[10,146] Agricultural uses of the catchment have not changed substantially in the past decade, with the last major expansions in the 1990s.[10]

As with other sectors of the Queensland economy, there is a degree of uncertainty around future trends in agriculture, especially in relation to global economic trends and the value of the Australian dollar.[4,147]

Future development scenarios have been predicted to place even further pressure on the Great Barrier Reef through higher pollutant loads from multiple sources.[4]

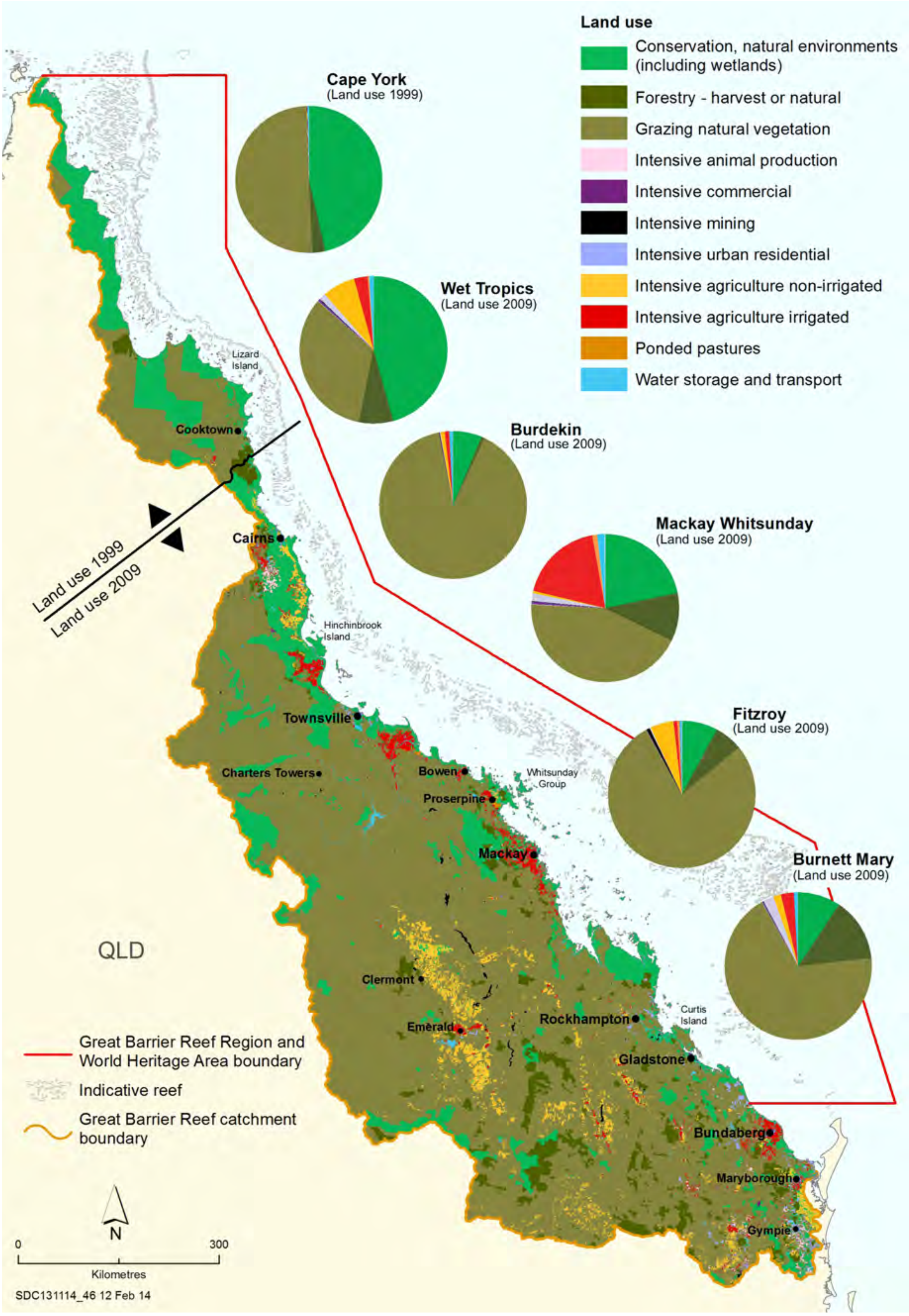


Figure 6.9 Land use in the catchment, 2009 and 1999
Grazing is the predominant land use in the catchment. Intensive agriculture is confined to a relatively small area, mainly close to the coast. For much of the catchment, comprehensive land use mapping was undertaken in 2009. For the Cape York natural resource management area, the most recent information is from 1999. Source: Queensland Government 2014[146]

The 2008 scientific consensus statement on water quality[148] concluded that implementation of the *Vegetation Management Act 1999* (Qld) was responsible for reducing the extensive land clearing of the previous decades. This legislation was identified as a critical element in beginning to address the impacts of land use on Reef water quality that had been reported from the 1970s to the late 1990s.

In 2013, the Queensland Government proposed changes to the Vegetation Management Act including repealing regulations that apply to clearing high value regrowth on freehold and Indigenous lands; allowing broadscale clearing for 'high value' intensive agricultural production; and promoting self-assessment of areas that contain remnant or high value regrowth.[149] Risks associated with changes to the legislation include the potential intensification of coastal agricultural development, with subsequent increases in pollutant loads.[150] The effect of these changes is unknown as the regulatory reform process is still underway.

Resource extraction activities in Queensland have continued to expand.

Mining The Great Barrier Reef catchment is rich in mineral resources and has long supported significant mining activity.[151] Historically, there have been extensive small-scale mining operations through much of the catchment, including gold, tin, nickel and uranium mines.[152,153]

More recently, the continued and increasing global demand for coal[154] has resulted in mine expansions, new mines and additional mine proposals within the catchment and in areas further inland. Production of saleable coal in Queensland has more than doubled since the early 1990s (Figure 6.10) and the Region is now associated with some of the world's largest mines and coal ports[155,156], along with the connecting infrastructure required to support them (Figure 6.3).

The projected Queensland export volumes for coal in 2025 range from 79 to 185 million tonnes for thermal coal and 226 to 262 million tonnes for metallurgical coal.[161] Over this period, coal production is projected to increase significantly in the Bowen, Surat and Galilee basins which export coal through the Great Barrier Reef.[161] Coal exports affect the Region's ecosystem and heritage values in two ways. The continued use of fossil fuels globally is the major driver of climate and ocean change, and servicing the export of coal is the major driver of port expansion along the Region's coast and population growth in the catchment.

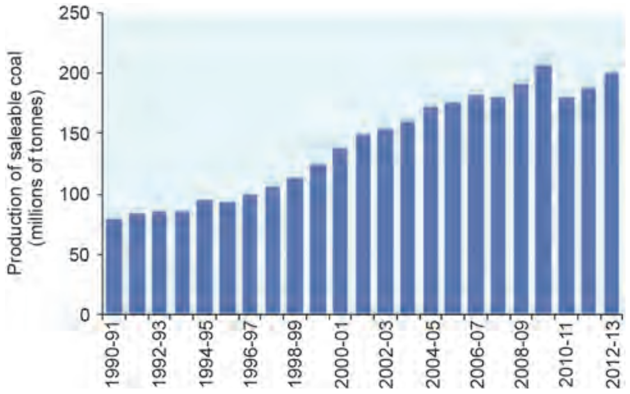


Figure 6.10 Production of saleable coal in Queensland, 1990–91 to 2012–13
Production of saleable coal in Queensland has increased two and a half-fold since 1990–91. Source: Australian Bureau of Statistics 1994[157], 1998[158], 2000[159], 2013[160] (ABS data used with permission from the Australian Bureau of Statistics)

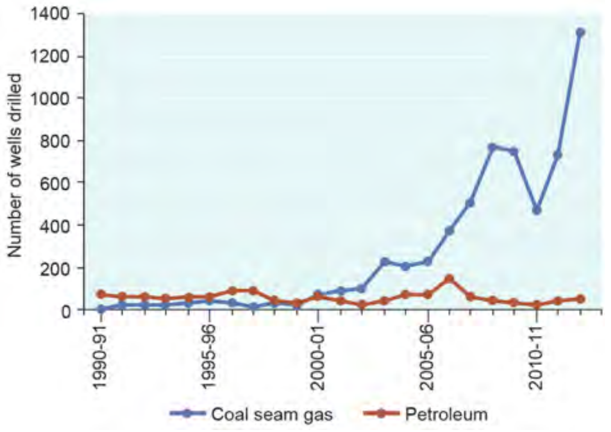


Figure 6.11 Wells drilled in Queensland, 1990–91 to 2012–13
Activity associated with coal seam gas has grown substantially over the last decade. Source: Department of Natural Resources and Mines (Qld) 2013[162] and 2014[163]

Queensland has 98 per cent of Australia's proven coal seam gas reserves and economic activity associated with the development of coal seam gas projects has grown substantially over the last decade (Figure 6.11). A 2012 report anticipates that Australia will become the world's largest liquid natural gas exporter by 2020 with a projected export of between 25 and 33 million tonnes for Queensland.[161] Curtis Island, within the Great Barrier Reef World Heritage Area, is the site for the world's first project converting coal seam gas to liquefied natural gas.[3]

Recent revocation of uranium[152] and shale oil mining bans[164] in Queensland may result in an increase in these mining activities in the catchment and transportation of material through the Region.

The area used for mining activities in the catchment almost doubled from 74,847 hectares in 1999 to 125,579 hectares in 2009.[146] There are a number of resource development projects proposed or under assessment. Changing global economic circumstances mean it is difficult to predict the number that will reach construction and production.

Urban and industrial development Urban and industrial development, excluding mining, in the Great Barrier Reef catchment is not extensive; however, future economic projections (Section 6.2.1) suggest an increase in both land uses. Continued population growth in coastal areas (Section 6.2.2) is increasing the demand for infrastructure and services such as roads, water, sewerage and power. If poorly planned and implemented, urban and industrial development can further modify coastal habitats and affect critical hydrological processes and ecological connections to the Great Barrier Reef.

Although urban areas occupy only a small proportion of the catchment (less that 0.01 per cent), much of the development is located on floodplains and within the coastal zone adjacent to the Region. This includes development of additional coastal infrastructure to improve access to the marine environment, either through the expansion of already popular facilities or the construction of new facilities in undeveloped sites.

Urban and industrial development within the coastal zone, and some activities associated with agriculture[165], can also result in the exposure of potential acid sulphate soils. These soils are found along the Region's coast in mangroves, saltmarshes, floodplains, swamps, wetlands, estuaries, and brackish or tidal lakes.[166] When they are disturbed and exposed to air they produce sulphuric acid, often releasing toxic quantities of iron, arsenic, aluminium and heavy metals.[167]

Increases in urban and industrial land use are expected; their current footprint is small.

Port development Activities associated with ports span jurisdictional boundaries, occurring on land, as well as in the Region. The land-based aspects of port development are assessed in this section. Those port activities undertaken directly in the Region are described and assessed in Section 5.5 and summarised in Section 6.6.

Port development has been the major reason for coastal reclamation — infilling areas of ocean, wetlands or other water bodies — along the Great Barrier Reef coast. For example, 14 million cubic metres of dredge material has been disposed to the Fisherman's Landing reclamation area in Gladstone Harbour as part of the development of Gladstone's port facilities. The total area reclaimed within the Great Barrier Reef World Heritage Area since its listing in 1981 is approximately eight square kilometres, based on a comparison of spatial information from the 1980s and best available data. The majority of this area is in the Gladstone region (approximately 5.5 square kilometres).

There has been major growth in port activity along the Region's coast.

Port development can also create artificial barriers to freshwater flow, such as bund walls and infrastructure in waterways.

There is a small risk of atmospheric and aquatic pollution from coal dust in areas where coal is handled or open to wind erosion.[168]

Aquaculture Land-based aquaculture occurs in the catchment, principally for prawns, barramundi, redclaw and freshwater fishes.[169,170] Aquaculture operations are located close to the coast in a number of areas in the southern half of the catchment, typically where there is access to good water supply. While over the last decade there has been little spatial expansion of land-based aquaculture adjacent to the Region, overall production has increased.[169] Before 2010–11, prawn aquaculture experienced strong annual production increases; however production fell by 25 per cent in that year mainly due to cyclones.[169]

There has been limited marine-based aquaculture within the Region and no facilities are in operation at present.

Island development Some of the Great Barrier Reef islands support residential areas and tourism resorts. Island developments can influence the Region's environment, and island residents and tourists undertake activities in the Region.

The principal residential islands are Palm Island and Magnetic Island, with populations of about 2400 and 2200 respectively.[171]

There are tourism resort developments on 27 Great Barrier Reef islands, including Lady Elliot Island, a Commonwealth island within the Region. Resort islands are located along the length of the Reef, with most in the Whitsundays (for example on Hamilton, Hayman, Lindeman, South Molle and Long islands).

Over the last decade, many island resorts have felt the effects of the economic downturn and extreme weather events, and some have stopped operating for a period. For example, the resort on Dunk Island remains closed after cyclone Yasi in 2011. Most island resorts have infrastructure extending into the Region including jetties, marinas, sewage outfall pipes, inlet pipes and cables — some of these are in poor condition or nearing the end of their working life. There are current proposals to redevelop some, for example replacement of the jetty at Orpheus Island.

A major redevelopment of Great Keppel Island resort was approved in 2013, including a hotel, villas, apartments, a golf course, a marina, plus services and facilities, including underwater power, water and communication. There is also a current proposal to redevelop Hook Island resort which is currently closed.

Hamilton Island in the Whitsundays is a major tourism resort © Chloe Schauble

6.4.2 Vulnerability of the ecosystem to coastal development

Changes in land use over the last two centuries have determined the extent and condition of remaining natural ecosystems in the catchment. Overall, approximately 60 per cent of pre-clear vegetation — classified as remnant vegetation — remains intact in the catchment (see Figure 3.12).[10] However, the status of coastal ecosystems varies greatly across basins (see Section 3.5).

Coastal development continues to modify coastal ecosystems (see Section 3.5) and their functions. This has flow-on implications for the Great Barrier Reef ecosystem and its outstanding universal value as a world heritage area.

Clearing or modifying of coastal habitats (such as saltmarshes, freshwater wetlands, forested floodplains and estuaries) close to the Region has significant effects on the feeding and reproduction of many marine species, as well as diminishing dry season refuges.[10] For example, where forested floodplains have been lost through changes in land use, the areas no longer provide nesting habitat or roosts for waterbirds and shady migratory pathways for aquatic species with connections to the Great Barrier Reef.[10] Another example is the replacement of coastal grasslands with intensive agriculture or urban settlements, reducing breeding habitat for many bird and reptile species, including estuarine crocodiles.[10,172,173]

The volume and speed of freshwater inflow can also be increased through coastal development activities such as clearing vegetation, hardening surfaces and straightening channels.[174] These effects are likely to be amplified as the climate changes.

Coastal reclamation has local effects on the Region's environment, for example removing coastal habitats, permanently destroying marine habitats (such as seagrass meadows), altering small-scale local currents, impeding natural drainage from the catchments, altering groundwater flows and diminishing local aesthetic values. If not properly managed, reclamation works can affect water quality in adjacent waters and potentially expose acid sulphate soils.

Coastal habitat changes and reduced connectivity affect the Region.

Artificial barriers to riverine and estuarine flow, such as dams, weirs, barrages, gates, levees, ponded pastures and weeds are widespread in the catchment. They affect the natural hydrology of the catchment and those Great Barrier Reef species that move between freshwater habitats and the sea. Many marine and estuarine fish species use the freshwater systems for part of their life cycle[175] and can be affected by changes in water flow and the presence of artificial barriers. Artificial barriers have disrupted sediment supply to some beaches.

The mobilisation of large quantities of iron and aluminium and heavy metals in surface and groundwater following the exposure of potential **acid sulphate soils** can affect many species at a local scale, both immediately and through accumulation in food chains. Examples include mangroves, seagrass meadows, invertebrates and fishes. In addition, south of the Region, exposure of the soils has been linked to algal blooms such as the toxic *Lyngbya* species.[176] The effects are often long term and difficult to reverse.[177,178]

The localised presence of **artificial light**, sometimes exacerbated by removal of beachfront vegetation and topography, affects some species. They can be attracted to or deterred from light or become disorientated, and foraging, reproduction, communication and other critical behaviours can be disrupted.[179] Artificial lighting can disorient nesting female turtles and their hatchlings by reducing the dominance of natural lighting cues.[180,181] Seabird fledglings have been found to be attracted to artificial light, causing them to land and stay in urban areas.[182]

Development of ports such as Townsville has involved reclamation of marine areas

Due to the relatively minor and localised urban and industrial development along the Region's coast, **atmospheric pollution** (excluding the contribution to climate change of gases such as carbon dioxide) is currently not a threat to the ecosystem. There is growing evidence about the potential threat of coal dust in the marine environment.[183,184] The increase in coal handling has increased the likelihood of coal dust entering the Region's ecosystem and there is a lack of knowledge around its potential chemical and physical effects.[185] Australian coal has relatively low trace element concentrations.[168]

6.4.3 Vulnerability of heritage values to coastal development

As many of the Region's heritage values are connected with a place, species or the whole ecosystem, impacts from coastal development on the ecosystem (Section 6.4.2) are relevant to assessing the vulnerability of heritage values — particularly natural heritage values, Indigenous heritage values and the Reef's outstanding universal value. The following are additional examples of their vulnerability to coastal development.

Indigenous heritage values and world heritage attributes relating to Traditional Owners' interaction with the environment are vulnerable to **clearing and modifying of terrestrial habitats**. For example:

- timbers that were once abundantly available to make tools are no longer found along much of the coastline[186]
- in Dharumbal country, coastal pandanus was and still is used for making baskets and matting, but its distribution and abundance has been greatly reduced[187]
- the distribution and abundance of the corkwood tree, a well-used and important tree for Wulgurukaba Traditional Owners, has been reduced[188]
- a traditional burial site, including 40 human remains, was disturbed in the late 1990s when a dam was built on the north side of Palm Island[189]
- traces of the 'big Murri camps' are 'long gone' along the shores of Cleveland Bay and Ross River[190].

Any changes to land and seascapes are changes to Traditional Owners' country and are likely to diminish culture and heritage values such as story places, songlines and sacred sites.

Modifying habitats directly adjacent to the Region also degrades the scenic amenity of the Region, recognising that people identify natural scenes of the ocean, rocks, white sand and natural coastal vegetation without any evident development as top-rating views[191].

Development of island resorts can affect the Region's heritage values — a factor taken into account in relevant impact assessments. Traditional Owners' cultural values and world heritage attributes relating to their interaction with the environment, as well as people's personal attachment more broadly, can be diminished by the scale and nature of the built infrastructure and the resulting increasing use, for example the development of island resorts. World heritage values may be affected by changing the naturalness and integrity of an area.

Historically, some **coastal reclamation** has been undertaken without proper engagement or consultation with Traditional Owners, resulting in effects on Indigenous heritage values. For example:

- in the Nelly Bay harbour development on Magnetic Island there was an incident that involved digging up of human remains[192]
- Bindal Traditional Owners have reported that Ross Creek fish traps have disappeared due to reclamation, meaning it is no longer possible to pass on this traditional practice to future generations[193]
- at Clump Point near Mission Beach — a culturally important story place — changes due to development mean the storyline involving the shape of the bay and headland is broken and the significant cultural site has been affected[194].

Coastal development has affected Indigenous heritage values.

In addition, historic heritage values can be affected by modification of coastal landscapes and reclamation of the coast. For example, there is the chance that unidentified wrecks may have been buried or disturbed in previous coastal reclamation projects and there is the potential for historically significant landscapes to be affected, such as places recorded or visited by early explorers. Built heritage, underwater wrecks and historic sites that are more remote within the Region are likely to be less affected by coastal development.

Species that are of cultural significance to Traditional Owners can be impacted by coastal development. Marine turtles and seabirds can be affected by **artificial light**, and some fish species are affected by **artificial barriers to flow**.

6.4.4 Implications of coastal development for regional communities

Access to the Region improves through development of coastal infrastructure.

Coastal development can have a range of positive and negative effects on the social and economic values of the Region. The construction of coastal infrastructure such as marinas and boat ramps will improve access and is likely to increase the number of people that derive enjoyment, appreciation and understanding of the Region's values through direct experience of the Region. It is also likely to cause increases in the economic value of Reef-dependent activities, for example by improving both tourism operators' ability to access the Region and visitors' ability to reach regional tourism nodes. Development of island resorts has the potential to provide greater access to the Region and to improve economic wellbeing of local communities by providing employment and income.

Economic and social benefits depend on healthy coastal and marine ecosystems.

It may be assumed, however, that the benefits of coastal development will only remain positive if the ecosystem services provided by adjacent terrestrial and island ecosystems are not diminished. For example, the clearing of coastal habitats and installation of artificial barriers to flow can have negative effects on the economic value of the Region's fisheries.[195,196] Barriers to flow can prevent some migrating fishes, such as barramundi[197], from accessing their breeding grounds, potentially resulting in declines in fish replenishment and ultimately catch rates. Island resorts can also negatively affect social values, for example by disrupting established use patterns and affecting the aesthetic values of an area.

6.5 Land-based run-off

A range of land uses occur within the catchment (and on islands) (Section 6.4). Associated practices such as pest control, the application of fertilisers, stocking rates, stormwater and sewage management, and earthworks influence the quality and amount of freshwater that flows into the Region. Components of run-off known to affect the Region's values include nutrients, sediments, pesticides and other pollutants such as heavy metals and plastic debris. Some land uses result in diffuse contributions, while others have a more point-source signature. While the contribution of pollutants from terrestrial point source discharges, such as mining and industrial releases, sewage, wastewater and stormwater, is relatively small compared to diffuse pollutant sources, discharges can be locally significant.[73]

6.5.1 Trends in land-based run-off

Legacy actions and contemporary land use continue to influence run-off to the Region.

Declining water quality associated with legacy and contemporary land-based run-off continued to be a major influence on the Region's values over the past five years. In response, the Australian and Queensland governments have committed to continue delivery of the updated *Reef Water Quality Protection Plan 2013*[198] (Reef Plan) to work towards the 2020 goal '*that the quality of water entering the reef from broadscale land use has no detrimental impact on the health and resilience of the Great Barrier Reef*'.

As a result of the continued investment by the Australian and Queensland governments, with support from regional natural resource management bodies, industry groups, participating landholders and other organisations, there has been significant progress by the agricultural community towards land management practices that improve land-based run-off to the Great Barrier Reef.[73] Between 2009 and 2013, 49 per cent of sugarcane growers, 30 per cent of graziers and 59 per cent of horticulture producers within the Great Barrier Reef catchment adopted improved practices.[199,200] The 2013 scientific consensus statement[73] concluded that '*water quality modelling, supported by appropriate validation, indicates that early adopters of best practice land management have reduced total pollutant loads — a significant step towards the goal of halting and reversing the decline in water quality to the reef*'. This has improved since the 2008 scientific consensus statement[148] which concluded that '*current management interventions are not effectively solving the water quality problem on the Great Barrier Reef*'.

However, the Reef Plan[198] also notes that '*while progress in the adoption of improved practices on the ground has been encouraging, it will take time for these achievements to translate into improved conditions in the marine environment. In fact, the marine condition has declined in recent years because of the impact of larger and more frequent floods and episodic events in adjacent catchments. The flood events are thought to have triggered another crown-of-thorns starfish outbreak*'.

Inshore areas are particularly at risk from poor water quality.

Understanding the cumulative effect of multiple pollutant sources is critical to protecting the Region's values. A 2013 water quality risk assessment[201] identified inshore areas, particularly those south of Cairns, have been most at risk of poor water quality. Areas along the coast in the vicinity of Hinchinbrook Island, Townsville and Gladstone showed a very high combined water quality risk, whereas the water quality risk in areas north of Cairns and in offshore areas was distinctly lower (Figure 6.12).

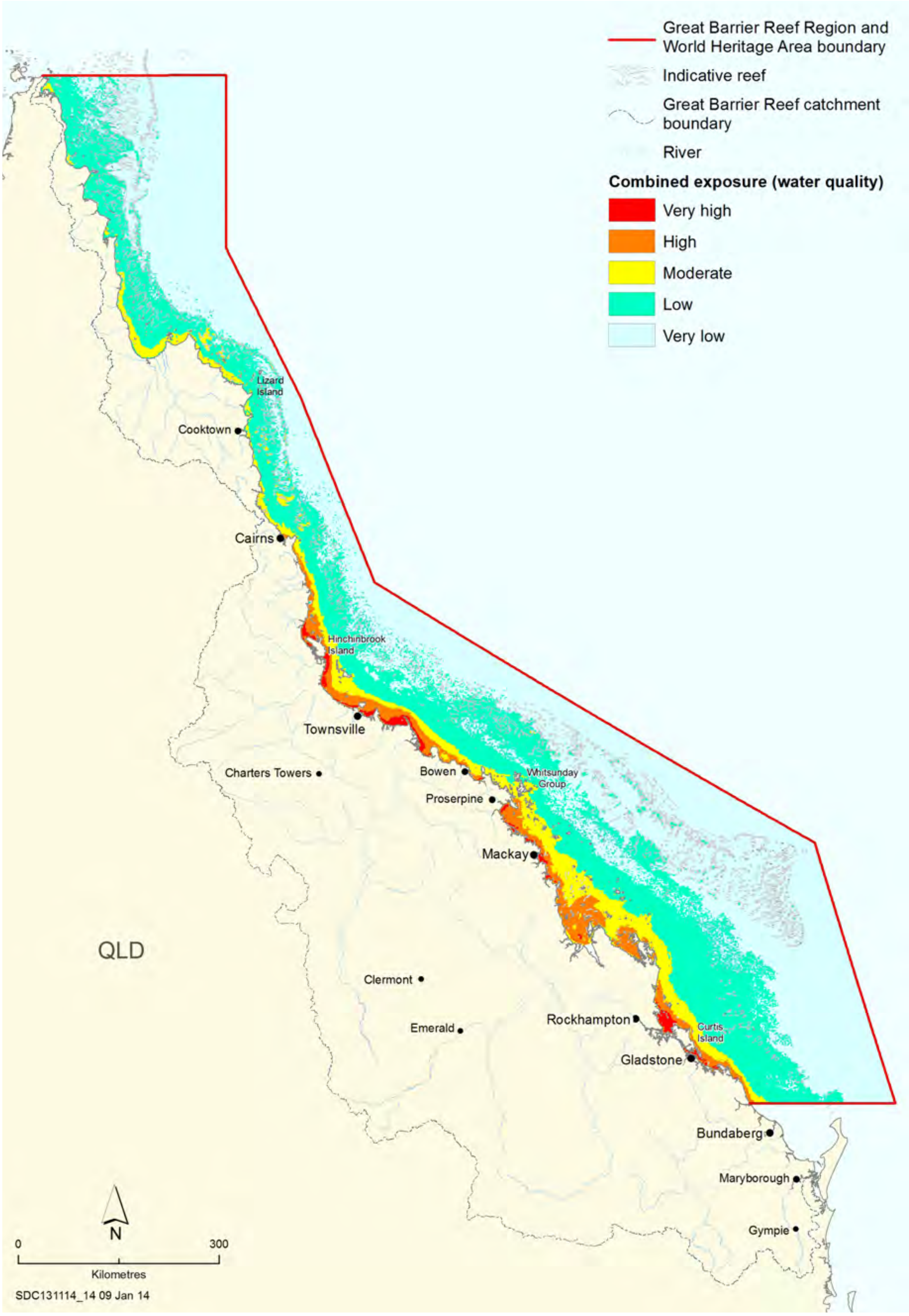


Figure 6.12 Exposure to key water quality factors
The map illustrates a combined assessment of: total suspended sediments (exceedance of 2 milligrams per litre and 6 milligrams per litre thresholds, 2002–2012, and average annual surface exposure, 2007–2011); nutrients (chlorophyll exceedance of 0.45 micrograms per litre thresholds, 2002–2012, and dissolved inorganic nitrogen average annual surface exposure, 2007–2011); PSII herbicide exposure, 2010–2011; and crown-of-thorns starfish initiation zone. Source: Brodie et *al.* 2013[202]

Nutrients Sources for nutrients into the Great Barrier Reef system include river discharges[203], urban run-off[204,205], atmospheric input[206], nitrogen fixation by marine organisms[207], deep ocean supply from upwellings[208], deposition of dust from storms and wind[209], and resuspension of nearshore sediments[210,211]. Of these, the single largest source is dissolved inorganic nutrients in river discharges[212], largely derived from fertilisers lost through run-off. Nutrients are also transported as part of the sediment load bound to particulates (particulate nutrients).[213] More than 90 per cent of the river discharges occur during the wet season.[205,214,215]

The nutrient load 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. Particulate nitrogen, often bound to fine sediments, is by far the largest load of nitrogen entering the Great Barrier Reef.[216] When re-mineralised it becomes readily available for uptake in marine ecosystems.

Dissolved inorganic nitrogen and phosphorous continue to enter the Great Barrier Reef ecosystem at greatly enhanced levels compared to those prior to European settlement. Estimates based on 2013 modelling suggest the total nitrogen discharge into the Great Barrier Reef ecosystem has increased from 20,077 tonnes annually before European settlement (late 1800s) to 35,053 tonnes annually.[217] Similarly, it is estimated that total phosphorus discharge has increased from pre-European settlement loads of 2727 annually to 5849 based on 2013 modelling.[217]

While the inshore ecosystem has always been exposed to higher concentrations of nutrients than further offshore, exposure inshore has substantially increased and is extending further offshore.[202,218] Contemporary exposure of the Region to the nutrient nitrogen is presented in Figure 3.9.

Nutrients in the marine environment can be estimated by measuring chlorophyll concentrations, as the amount of planktonic algae containing chlorophyll in the water column is proportional to nutrient concentrations. Monitoring and modelling indicate that chlorophyll concentrations have exceeded the *Water Quality Guidelines for the Great Barrier Reef Marine Park*[219] in up to 10 to 15 per cent of the Region over the last decade (Figure 6.13).[220] For much of the central and southern inshore environment, concentrations are frequently above the annual guidelines, with some areas more than double.

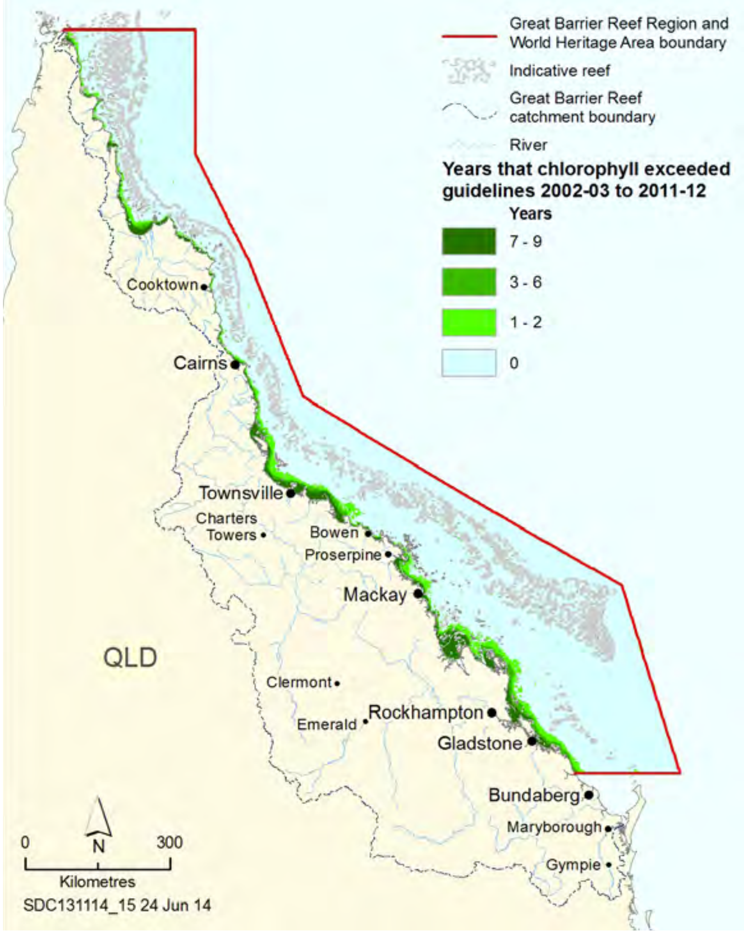


Figure 6.13 Years that chlorophyll concentrations exceeded guidelines, 2002–03 to 2011–12
The water quality guidelines for the Great Barrier Reef Marine Park use chlorophyll concentration as an indicator for nutrient concentrations in open waters. The guideline trigger value is an annual mean of 0.45 micrograms of chlorophyll per litre — an important ecological threshold for macroalgal cover and coral species richness. The map shows the number of years that the guideline value was exceeded between 2002–03 and 2011–12. Source: Brodie *et al.* 2012[202]

A key target of Reef Plan 2013[198] is to achieve a 50 per cent reduction in dissolved inorganic nitrogen loads entering the Great Barrier Reef by 2018. Total fertiliser use on farming lands in the catchment has been reduced in recent years (Figure 6.14) and monitoring and modelling show current initiatives are successfully reducing nutrient concentrations in land-based

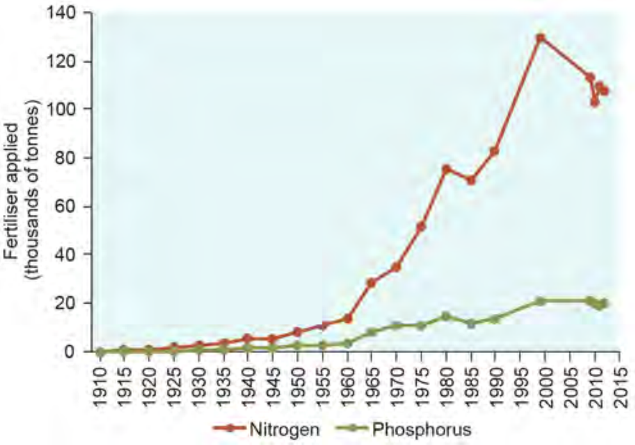


Figure 6.14 Fertiliser use in the catchment, 1910–2012
After decades of increasing fertiliser use in the Great Barrier Reef catchment, calculations indicate the amounts used are now lower or at least stabilising. Sources: The 1910 to 1990 data was derived from Pulsford 1996.[223] The 1999 and 2009 to 2012 data points were estimated using 1999 and 2009 Queensland Land Use Mapping Program data[224], the 2000 Fertilizer Industry Association of Australia application rates for different land uses[225],and 1999–2012 Incitec Pivot published figures estimates of nutrient application rates in sugar production.[226]

run-off. There was an estimated ten per cent reduction in nitrogen and a thirteen per cent reduction in total phosphorous loads as at June 2013, compared to the 2009 baseline year.[200]

There have been reductions in the nutrient loads delivered to the Region.

Early evidence shows reductions in the load entering the marine system has resulted in reduced nutrient concentrations in open waters.[221,222]

However, the trajectory of reduction in the nutrient loads suggests that the present best management practices are unlikely to achieve the targets needed to address the impacts of the nutrients on the Great Barrier Reef ecosystem. The 2013 scientific consensus statement noted that '*while current management interventions are starting to address water quality... in addition to continuous improvement, transformational changes in some farming practices may be necessary to reach some targets*'.[216]

Many sewage treatment plants along the coast have been upgraded.

Sewage treatment plants occur along the length of the southern and central Great Barrier Reef coast. The Outlook Report 2009 highlighted that under Queensland Government policy all coastal sewage treatment plants that discharge into the coastal and marine waters were required to meet the most stringent treatment standards (tertiary treatment) by 2010. Most of the major population centres adjacent to the Great Barrier Reef, with the exception of Rockhampton, now have upgraded sewage treatment plants. Some upgrades are still underway in smaller population centres. The total cost of these upgrades has been between $600 and $700 million since the early 2000s, with investment from all levels of government and the community.

While inputs of nutrients from sewage treatment plants accounted for only a small percentage of the overall load entering the Region from the catchment[110], the reductions gained through upgrades can be quite significant at a local scale. Sewage treatment upgrades in Townsville, for example, reduced the nitrogen load into Cleveland Bay from its catchment (the Black and Ross rivers) by around 42 per cent.[227,228]

Sediment load to the Region has been reduced but ecosystem results will not be seen immediately.

Sediments The Outlook Report 2009 reported estimates of a four to eight-fold increase in sediment loads since European settlement.[229] Recent modelling has improved earlier estimates for both historical and contemporary loads, and suggests the suspended sediment load entering the Reef has increased to 7930 kilotonnes per year from the pre-European settlement load of 2931 kilotonnes.[217] The increase in sediment load is mainly due to soil erosion, exacerbated by poor land management practices and the highly variable rainfall patterns in some areas. In addition, hardened surfaces and straightened channels, as a result of urban and industrial development and agriculture, mean run-off has more erosive power, increasing stream bank erosion.

Much of the central and southern inshore area of the Region is now frequently affected by increased suspended solids (Figure 6.15 and see Figure 3.4). Most sediment is confined to the inner shelf and settles out of the water column within five to 15 kilometres of the coast[230,231,232] where it may be later resuspended by wind-generated waves and currents. However, during flood events, suspended sediment may be carried further offshore. For example, during the 2010–11 wet season, when the Burdekin River had highly elevated discharge over 200 days, most sediment initially settled within approximately 10 kilometres of its river mouth, but some fine silt and clay was carried as far as 100 kilometres northward.[233] These fine sediments also carry nutrients and other contaminants further into the Region.[234,235]

A key target of Reef Plan is to achieve, by 2018, a 20 per cent reduction in sediment loads entering the Region as a result of human activities. Improvements in land management practices have already achieved an eleven per cent decrease in the overall sediment load entering the Great Barrier Reef since 2009.[199] However, it takes time for any changes on land to translate into improved marine condition[236], particularly given the lags in sediment transport and the strong influence of severe weather events in recent years.

Pesticides including herbicides, insecticides and fungicides, are used to kill or control pests and weeds in agricultural and urban environments and would

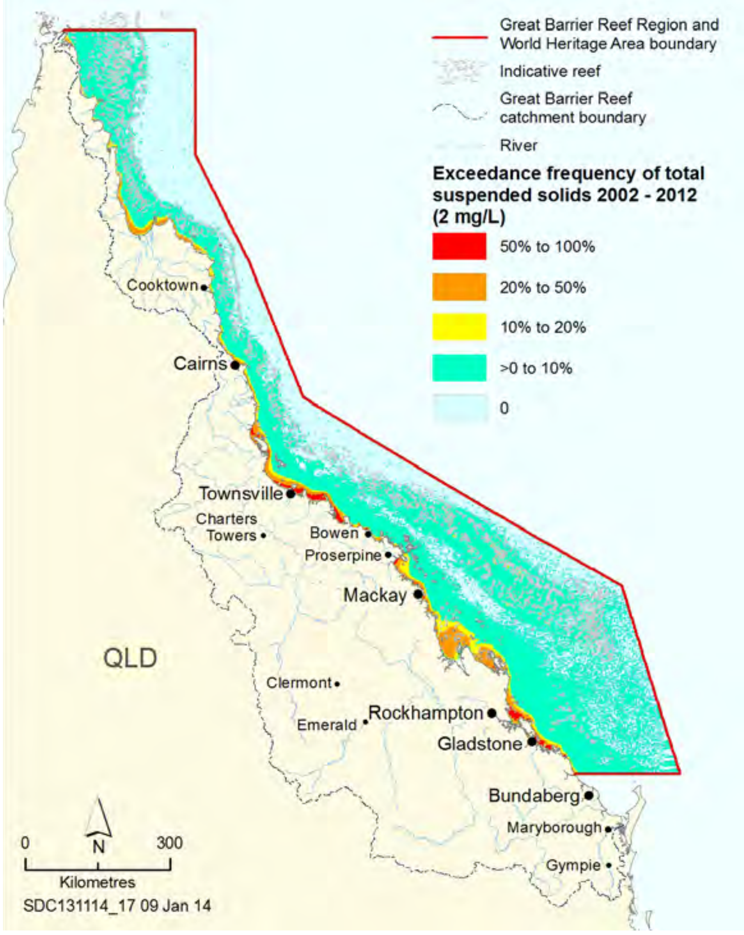


Figure 6.15 Frequency of total suspended solids above guidelines, 2002–2012
The map shows the proportion of valid daily observations that exceeded the total suspended solids guideline of two milligrams per litre in the Region. The period of observations extends from 1 November 2002 to 30 April 2012. Source: Brodie *et al.* 2013[202]

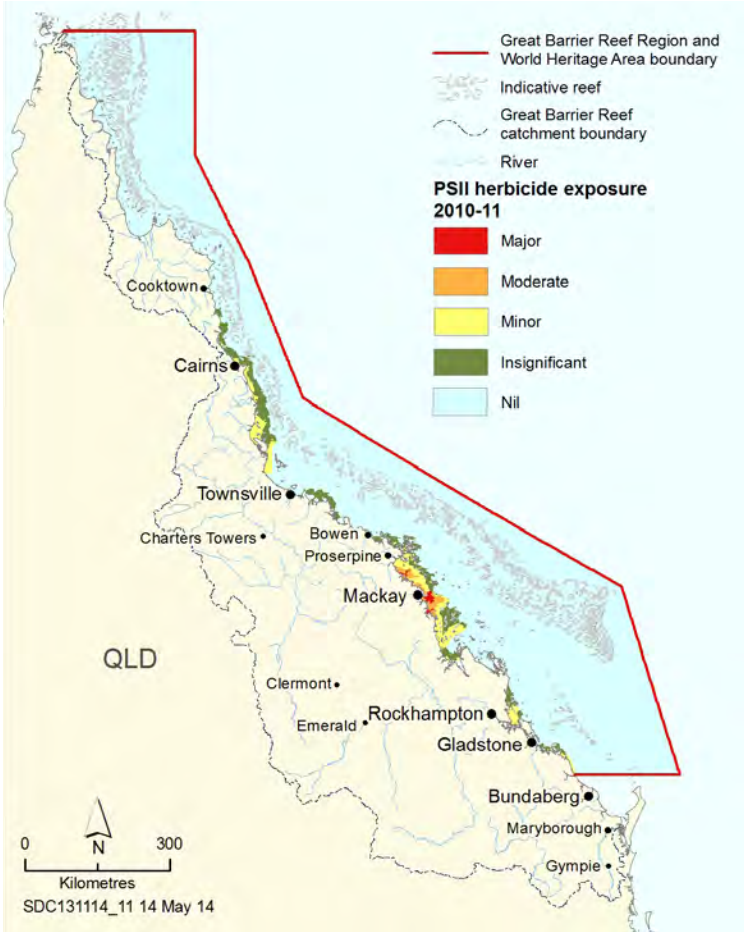


Figure 6.16 Modelled exposure of additive PSII herbicide residues, 2010–11

The map shows risk areas for photosystem II inhibiting (PSII) herbicide residue based on modelling. The model calculated additive PSII herbicide concentrations using end-of-river monitoring data. The established relationship between concentration of dissolved organic matter and salinity was applied to corresponding satellite images of flood plumes to predict the additive PSII concentrations. Conservative mixing processes in the Great Barrier Reef lagoon were assumed. Exposure categories were based on known toxicity thresholds for coral and seagrass species. Source: Lewis *et al.* 2013[247]

have been absent from the Region's environment prior to European settlement.[237] It is estimated from 2013 modelling that at least 12,114 kilograms of herbicides are now introduced into the Region each year from diffuse source agricultural run-off.[217]

Systematic monitoring of pesticide residues[238] has shown widespread contamination by a range of pesticides in rivers, streams and estuaries that drain to the Region[237], with the highest exposure around Mackay. This includes frequent exceedances of the Australian and New Zealand Water Quality Guidelines for fresh waters[239] (often 10 to 50 times), for example atrazine and diuron, in some rivers.[240] However, a 2013 risk assessment undertaken as part of the review of Reef Plan has shown that in the Region the highest pesticide risks are confined to only a couple of locations (Mackay region and the lower Burdekin area).[202] Concentrations of pesticides in waters around reefs remains generally very low.[241]

Elevated herbicide concentrations in the Region (Figure 6.16) have been particularly linked with sugarcane cultivation in the adjacent catchment.[242,243,244] Irrigation shortly after herbicide application is a major contributor to herbicide loss from farms.[245] The sugarcane industry has taken initiatives, many funded through the Australian Government Reef Programme, to reduce herbicides in run-off[246]; resulting in good progress in reducing pesticide losses to the environment. There has been a 28 per cent pesticide load reduction across the Region and a 42 per cent reduction in the Mackay region, the highest risk area.[199]

Other pollutants In addition to nutrients, sediments and pesticides, a number of additional pollutants generally associated with human development are currently, or likely to be, found in Great Barrier Reef waters. Examples include marine debris (including microplastics), pharmaceuticals and personal care products and trace metals.[185] As human populations along the coast grow, input levels may increase. There is little information or marine monitoring for most of these pollutants, other than marine debris.

Common items of marine debris found within the Region are plastic bags, discarded fishing gear, plastic and glass bottles, rubber thongs, aerosols and drink cans.[248] Plastic is the most prevalent type of marine debris found on beaches worldwide, comprising between 50 to 90 per cent by number of all debris items recorded.[249,250,251,252] Between 2008 and March 2014, about 683,000 individual items of marine debris, weighing over 42 tonnes, were collected from the Region's beaches by volunteers in the Australian Marine Debris Initiative.[249] Marine debris from the catchment appears to accumulate and remain confined within the lagoon system of the Reef but with a northward movement.[248] At the southern end of the Reef, debris appears to be more ocean-sourced.[248] Stormwater run-off receives no treatment (other than gross pollutant traps for some drains)

Communities are working to reduce stormwater contributions to marine debris.

Townsville City Council, a Reef Guardian council, has stencilled entries to stormwater drains and therefore any chemicals or rubbish it contains can flow into creeks or rivers and into the marine environment. To improve the quality of stormwater and reduce marine debris, local councils are working with their communities and Queensland government agencies to better manage water flow, rubbish disposal and the use of chemicals.

Industrial discharge is subject to national, state and Great Barrier Reef-specific water quality guidelines that identify trigger levels on the discharge of chemicals such as metals, metalloids and non-metallic inorganics in wastewater.[110] However, many facilities were built decades ago, with long-term permits containing a variety of conditions.

Marine pollutant benchmarking work in 2004 did not identify any significant toxic trace ('heavy') metal concentrations in the inshore waters of the Great Barrier Reef, especially when compared to levels in other Australian locations. Within the Region elevated levels of toxic trace metals have been reported at some sites around harbours and ports, but these are not necessarily above guideline levels.[236] Trace metals often accumulate in the food chain; testing of tissues from deceased dugongs within the Region has generally found low levels by world standards.[253]

In mid-2012, following consecutive years of above average freshwater flow in the Burdekin region, 102 marine turtles stranded in a short period of time in Upstart Bay. Of these, 82 were already dead. Severe neurological symptoms were common in the turtles found alive. Exploratory testing of blood and tissue samples[254] revealed cobalt levels potentially high enough to cause acute effects based on case studies in mammals[255,256,257]; comparative information for reptiles is limited[258]. The source of the cobalt and the circumstances under which the exposure occurred are not yet known.

Some pollutants from historical mining activity in the catchment have reached the marine environment through land-based run-off, especially after periods of heavy rainfall. Sediment cores from inshore areas near Townsville have shown a spike in mercury of 25 times the background levels (before European settlement) that coincides with a period of intense gold mining in the adjacent catchment area (between 1870 and the early 1900s) when mercury was used in gold processing.[259]

Some small-scale extractive mining operations have previously released toxicants that have had severe effects, at least locally, in streams and creeks, for example arsenic associated with tin mining near Herberton.[260] An emerging issue is the volume of water requiring disposal at mines and refineries after high rainfall events. A pilot program of allowing coal mine wastewater releases during flood conditions was implemented in the 2012–13 wet season for four coal mines in the catchment. This has subsequently been expanded to all coal mines within the Fitzroy basin.[261] It is anticipated that the results of monitoring associated with these releases[262] will improve understanding of the extent of any effects on water quality in the Region.

Inshore areas have recently been exposed to significant freshwater flow events.

Freshwater flows La Niña conditions increased average annual rainfall and flood events between 2008 and 2012 (see Figure 3.3)[35], resulting in inshore areas of the Region being exposed to freshwater. Heavy rainfall events could become more frequent in future as the climate changes (Section 6.3.1)[37]. Modifications to terrestrial habitats within the catchment (see Section 3.5) have affected the magnitude and timing of freshwater flows to the Region. For example natural flow has been altered and the velocity of discharges increased by infilling of wetlands, clearing of forests and woodlands, and constructing dams, levee banks, roads and stormwater drains.

Both the intensity and amount of rainfall and the velocity of freshwater flow affect how much sediment, nutrient, pesticide, plastic and other debris enters the Region from the land.

6.5.2 Vulnerability of the ecosystem to land-based run-off

Declining marine water quality, influenced by land-based run-off, is recognised as one of the most significant threats to the long-term health and resilience of the Great Barrier Reef.[73] It is contributing to declines in many of the attributes that make up the outstanding universal value of the world heritage property, particularly those related to coral reefs and seagrass meadows.

Links between poor water quality and ecosystem health are now better understood.

The 2013 scientific consensus statement[73] concluded that '*the decline of marine water quality associated with terrestrial run-off from the adjacent catchments is a major cause of the current poor state of many of the key marine ecosystems of the Great Barrier Reef. ... The greatest water quality risks to the Great Barrier Reef are from nitrogen discharge, associated with crown-of-thorns starfish outbreaks and their destructive effects on coral reefs, and fine sediment discharge which reduces the light available to seagrass ecosystems and inshore coral reefs. Pesticides pose a risk to freshwater and some inshore and coastal habitats*'.

Since the Outlook Report 2009, understanding of the effects of water quality changes on Great Barrier Reef species and habitats has continued to improve.[73] Research has strengthened evidence for causal relationships between water quality change and the ecosystem health of corals, seagrasses and mangroves, and for the effects of increased nutrients and sedimentation on the health and resilience of coral reefs.[73]

Nutrient cycle imbalances are affecting the ecosystem.

Nutrients from land-based run-off are considered one of the greatest threats to the Reef ecosystem.[216] Once dissolved inorganic nutrients enter the marine system, they are taken up by phytoplankton, bacteria and seafloor plants such as macroalgae and seagrasses. The addition of excess nutrients, to a certain level, can increase productivity across large areas and if the conditions are right can increase the survival rates of certain species.[213,263] This includes a variety of plants and animals in the marine system such as phytoplankton[264], macroalgae that compete with corals[220,265] and epiphytes that compete with seagrass[266]. An excess of nutrients can even lead to a change in the trophic status of an area of the marine environment and it is believed that this eutrophication is happening more regularly in the inshore waters of the Great Barrier Reef.[213,267,268]

Examples of the consequences of imbalances in the nutrient cycle as a result of elevated nutrients include:

- extensive, observable phytoplankton blooms in flood discharges and likely shifts in the species composition of phytoplankton[213,269]
- links to an increase in the frequency of crown-of-thorns starfish outbreaks (see Section 3.6.2)
- may contribute to a shift in the balance between macroalgal and coral abundance
- may make corals more sensitive to temperature stress[270,271]
- may facilitate disease outbreaks in coral by increasing the virulence of their pathogens or reducing their immune responses[272,273]; the nutrient organic carbon contributes to this effect[274]
- increased growth of phytoplankton, macroalgae and algal epiphytes that lower ambient light levels, thus increasing competition for light and reducing photosynthesis in seagrass[275] and corals (particularly in deeper waters).

Sediments in land-based run-off have far-reaching effects on the Great Barrier Reef ecosystem. For example:

Elevated sediment loads and resuspension reduce light and smother plants and animals.

- Heavier erosion sediments infill freshwater stream beds and deep waterholes, with the reduced water depth affecting the distribution, abundance and recruitment of many freshwater species and some marine-related species such as sawfish[276].
- Increases in suspended sediment are significantly altering light regimes — lower light levels reduce primary production in both the water column and on the seafloor.[277,278]
- Increased amounts of sediments are settling on seafloor organisms such as seagrass and corals, making it harder or impossible for them to grow, survive and reproduce.[279,280] This has significant flow-on effects to organisms and animals dependent on these habitats.
- In some areas increased fine sediments from land-based run-off have resulted in mangrove forests replacing beaches.[33]
- The suspension and resuspension of sediments is increasing the turbidity of open waters and releasing additional nutrients previously bound up or buried in sediments.[269,278,281]

Inshore areas, particularly in the southern two-thirds of the Region, frequently exceed the water quality guidelines threshold for suspended sediment concentrations of two milligrams per litre[219] (Figure 6.15). This threshold correlates strongly with declines in ecosystem condition such as increased growth of macroalgae.[282] Concentrations above 6.6 milligrams per litre have been linked with coral stress[283], declines in seagrass cover[284], fish habitat changes[285], and home range movement[286].

Ecosystem effects of long-term exposure to pesticides are not well understood.

Pesticides in land-based run-off can have a negative impact on marine plants and animals.[240,242] Herbicide concentrations in flood plumes that extend into the marine environment can exceed concentrations shown to have negative effects on certain species of coral, seagrass and microalgae and present risks to marine mammals.[253,287,288,289,290] Despite this, current levels of pesticides are considered to be a low to moderate threat to inshore coral reefs generally, but the consequences of long-term exposure are not understood. The threat is likely to be higher in some regions, especially when pesticides are present in combination with other pollutants and stressors.[216]

Generally, natural freshwater flows enhance estuarine productivity, provide connectivity between freshwater habitats and the sea, and improve fish recruitment and growth.[291] Maintaining natural freshwater flows can have positive effects, for example on breeding and recruitment of estuarine and marine fishes of commercial and recreational value including barramundi and king threadfin.[292,293] However, **increased freshwater inflow** can have negative effects, for example low salinity bleaching and mortality in inshore corals[86] and widespread damage to seagrass meadows[95]. Investigations show that the poor health observed in a range of fish species in Gladstone harbour during 2011 was likely to be the result of multiple pressures, but in particular overcrowding of fish after an overspilling of Awoonga Dam during a high flow event.[155] Examination of a 17-year dataset for the urban coast of Queensland found peak mortality of dugongs followed sustained periods of freshwater discharge and low air temperature.[96]

While the contribution of key pollutants from **terrestrial point source discharge** is relatively small when compared to diffuse pollutant sources, the impacts can be locally significant.[73] There is no specific evidence linking pollutants such as heavy metals to declines in marine species in the Region, however they can persist for decades in the marine environment and have been shown elsewhere to disrupt reproduction, impair immune systems, affect neurological systems and cause cancers[294].

Marine debris poses a significant threat to wildlife © Chris Jones

Marine debris washed from the land continues to affect the Region's ecosystem.

Marine debris, including that introduced into the marine environment through land-based run-off, poses a significant threat to wildlife, including species of conservation concern. They can choke on it, ingest it, become entangled in it, or absorb chemicals from it.[295] In Australia, plastic waste, including discarded fishing gear (for example nets, lines and ropes), is potentially one of the most harmful types of debris to marine wildlife because of ingestion and entanglement.[296,297,298,299] Marine debris of all sorts can affect species and habitats throughout the Region.

Land-based run-off also plays a role in transporting terrestrial weed species onto islands within the Region.

6.5.3 Vulnerability of heritage values to land-based run-off

Many of the Region's heritage values, such as world and national heritage values, natural heritage values and Indigenous heritage values are vulnerable to the threats associated with land-based run-off through their effects on the ecosystem (Section 6.5.2). The threats associated with land-based run-off have affected many attributes that contribute to the outstanding universal value of the Reef, for example its coral reef and seagrass habitats and its underwater beauty.

Many heritage values are vulnerable to the effects of land-based run-off.

Particularly in inshore areas of the southern two-thirds of the Region, underwater aesthetic values are being affected by overall declines in ecosystem condition. These values are also being diminished by increases in turbidity as a result of **sediments** and **nutrients** in land-based run-off, combined with **marine debris**. It is likely that increased sedimentation is also affecting underwater historic heritage such as shipwrecks and World War II artefacts.

Cultural practices have been affected by concerns about heavy metal contamination of species of cultural significance, resulting from **terrestrial point source discharges**. High levels of heavy metals have been detected in the livers of turtles in the Torres Strait[300] and dugongs[253], which could pose health risks to Indigenous people. In the Gladstone region, some Traditional Owners consider the health of turtles to be so poor they have stopped taking them as part of their cultural practices.[301]

6.5.4 Implications of land-based run-off for regional communities

Ecosystem declines from poor water quality, particularly in inshore areas, affect Reef-dependent industries.

Declines in the ecosystem as a result of land-based run-off are likely to be affecting the income of Reef-dependent industries, especially commercial fishing and commercial marine tourism. Tourism operations are particularly affected by declines in coral reef ecosystems, such as those caused by increased sedimentation and increased nutrient concentrations. In addition, crown-of-thorns starfish outbreaks can diminish the biodiversity and natural beauty of high value tourism sites and therefore their attractiveness as a tourism destination. Increased turbidity may also affect the tourism industry as clear water is one of the main attributes valued by international and domestic visitors.[127]

Land-based run-off can also affect social values such as the personal connections, enjoyment and appreciation of an area. In a 2013 survey of visitors to the Region, the most important motivations for their visit were those relating to the state of the ecosystem, for example clarity of water, iconic species, healthy reef fish and healthy coral reefs (see Figure 5.6).[127] Marine debris, especially on islands and beaches, is a major factor determining people’s enjoyment of the Reef environment. Catchment residents and tourists surveyed in 2013 regarding what they value about the Great Barrier Reef indicated a lack of rubbish as one of the most important aspects.[127]

Enjoyment of the Region is likely being affected by water quality declines.

The need to improve the quality of land-based run-off flowing into the Great Barrier Reef is the major impetus for many community-based stewardship programs such as farmers and graziers taking actions to improve river habitats, minimise erosion and improve the effectiveness of fertiliser applications; local governments improving the quality of run-off from urban areas; and students building sustainable gardens and revegetating habitats.

6.6 Direct use

Direct use of the Region includes commercial marine tourism, defence activities, fishing, ports, recreation, research and educational activities, shipping and the traditional use of marine resources. The trends in direct uses are summarised from the relevant sections in Chapter 5. The analysis of the vulnerability of the Region’s values to direct use as a whole and its implications for regional communities are based on the evidence and assessments presented in Chapters 2, 3, 4 and 5.

6.6.1 Trends in direct use

Direct use activities continue to be a significant influence on the Region.

Commercial marine tourism From 2005 to 2011, the number of tourism visits to the Region generally decreased and in 2011 it was the lowest it had been for 13 years. Tourism visits have subsequently increased. Tourism activities and their associated threats to the Region’s values continue to be concentrated in a few popular, intensively managed areas. Despite the increasing financial pressures on the industry, there continues to be an increasing trend towards the achievement of high operating standards (environmental, economic and social), more tourists choosing to visit the Region on high standard operators, and contributions to monitoring and Reef stewardship. For all of Queensland, over the next decade, domestic tourism is predicted to grow at about 0.8 per cent annually[302] and international tourism at 4.2 per cent, with India and China as the principal drivers[303]. Most growth is likely to take place in regional areas[303] such as the Great Barrier Reef.

Defence activities The Region is likely to remain an important training area for defence activities. The Australian Defence Force is enhancing its capabilities in amphibious landings. As a result, more frequent and intensive amphibious training exercises are expected in the Region, particularly in Shoalwater Bay and Cowley Beach training areas. The United States of America has shifted its global military focus to enhance its capabilities in the Asia–Pacific region. This will likely increase the frequency and intensity of combined training exercises. The importance of Shoalwater Bay and other sites in the Region for major exercises will also increase.

Fishing The Region is likely to continue to be an important resource for Queensland fisheries. Global fisheries trends influence those for the Great Barrier Reef. As wild-caught fisheries throughout the world continue to be fully exploited or over exploited[304], the economic value of the Region’s fisheries resources, the pressure to exploit them (legally and illegally) and the demand for intensive aquaculture may increase.[110] In addition, fishing effort may spread northwards in the Region to take advantage of catch availability and improving market access (due to improved infrastructure), or to offset other factors such as impacts of extreme weather and increasing recreational use close to urban areas. Economic factors such as fuel prices[305] and the strength of the Australian dollar also influence patterns of commercial fishing operations.

The continuing increase in the number of registered vessels in the catchment, reflecting population and economic growth, is likely to translate into increases in recreational fishing effort. Likely ongoing improvements in vessel safety and navigation mean recreational fishers will be able to fish more remote areas.

Ports There has been major growth within ports in and adjacent to the Region over the past few decades and especially in recent years. From 2007–08 to 2011–12, trade volumes grew by over seven percent from 186 to 200 million tonnes per annum.[306] The worldwide trend towards longer, deeper draft ships[307] affects port access requirements, including increasing the need for dredging and infrastructure.

In relation to ports in and adjacent to the Region, the 2014 *Queensland Ports Strategy*[308] sets out the Queensland Government’s intention to concentrate development in five nominated priority port development areas of which four are adjacent to the Region — Port of Gladstone, ports of Hay Point and

Mackay, Port of Abbot Point and Port of Townsville. The aim is to maximise efficiencies and economic outcomes, while minimising environmental impacts. There is also a commitment to prohibit capital dredging for the development of any additional deepwater port facilities outside of the long-established major port areas until 2024.

Recreational use (not including fishing) The number of recreational visits from residents in the catchment appears to have risen substantially in recent years, most likely as a result of: population growth, an increase in the proportion of the population visiting the Region and a rise in the average number of visits each person makes.[309] Continuing increases in the population in coastal areas adjacent to the Region and in the number of recreational vessels[21] are likely to result in continued growth in recreational use. In addition, access to more isolated locations has been improved by developments in vessel safety and navigational technology.

Research and educational activities The Region is likely to continue to be an area of high scientific interest because of its ecological diversity, geomorphology and cultural heritage. Research will continue to make a substantial contribution to the way the Reef is understood, managed and used over coming decades. Technological changes are likely to continue to change both the way research and monitoring are conducted and the analysis of its results.

Continuing and expanding monitoring will play a key role in tracking trends in the Region's values, the factors that are influencing them and the effectiveness of management actions.

Shipping The number of ship voyages undertaken through the Region has increased substantially over the past 10 years. Shipping in the Region is predicted to significantly increase over the next 10 to 15 years, with the number of vessel calls forecast to more than double by 2032.[310] This will be driven mainly by growth in the mining and liquefied natural gas industry which subsequently drive port expansions and increases in trade.[154]

Traditional use of marine resources Traditional Use of Marine Resources Agreements and a marine Indigenous Land Use Agreement apply to approximately 13 per cent of the Region. This is likely to increase into the future given that additional Traditional Owner groups are working to develop agreements. With increased development in remote areas and changes to infrastructure, there is potential for the level and type of traditional use along the coast to change.

Use of the Region for recreation is likely to increase with population growth © Susan Sobtzick

6.6.2 Vulnerability of the ecosystem to direct use

Understanding of threats from direct use has improved.

Since the Outlook Report 2009, understanding of the threats associated with direct use has improved as has knowledge of some of their cumulative effects on the Region's values. For example, recent modelling indicates that dredged material disposed at sea may be travelling further than previously expected.[311] There is also better understanding of the risks of trawl fishing in the Region showing that, while the risks are generally low, some higher risks remain.[312]

Except for activities associated with fishing and ports, direct uses of the Region are likely to be having relatively minor effects on the ecosystem on a Reef-wide scale. However, their cumulative effects can be significant on a local scale, especially when concentrated inshore and next to developed areas. Some uses continue to have positive benefits through improving understanding about the ecosystem and contributing to management.

Dredging at the Port of Hay Point

Dredging and disposal directly affect local areas; uncertainty remains around broader effects.

Seagrass and lagoon floor habitats are removed, damaged or smothered at the sites of both **dredging** and **disposal of dredge material**. These activities can also cause behavioural changes, injury and mortality in dependent species, including in species of conservation concern. Habitats such as coral reefs, seagrass meadows and the lagoon floor and their dependent species are vulnerable to increases in the turbidity as a result of dredge sediment plumes and the **resuspension of dredge material**. The disposal of additional dredge material into the Region increases the risk of effects on vulnerable habitats and species.

Targeted species from various trophic levels are directly affected by **extraction** with flow-on effects in the ecosystem. Almost half the retained catch of the Region's fisheries are predators. In addition to affecting the abundance of the targeted predator species in fished areas[313,314], their removal is likely to have long-term effects[315], including direct and indirect effects on the food chain[316]. While there is currently only a small take of herbivores, significant increases could lead to effects higher up the food chain and changes in the abundance of plants, in turn affecting the balance of coral and algae for example. The ecosystem is still affected by the legacy of earlier commercial harvesting of larger herbivores such as dugongs and marine turtles. There can also be ecosystem-wide effects of **extraction from unprotected spawning aggregations**.[317]

Fishing continues to affect the Region's values, including discarded catch, incidental take and illegal fishing.

The benefits to the ecosystem from zoning and other management arrangements can be undermined by **illegal fishing and poaching** — a focus of compliance activities in the Region. In a number of areas dugongs, inshore dolphins and turtles are at risk of entanglement and drowning particularly because of illegal commercial netting.

Death and injury of **discarded catch** and the **incidental catch of species of conservation concern** during fishing operations, such as in the trawl and inshore net fisheries and the Queensland shark control program, can have severe effects on species and the broader ecosystem. Vulnerable species include dugongs, inshore dolphins and some species of sea snakes, seahorses, marine turtles, sharks and rays. Management requirements, such as bycatch reduction and turtle excluder devices in the trawl fishery, have reduced but not eliminated the risks to these species. Even low levels of mortality may cause population declines in species of conservation concern and compromise the ability of depleted populations to recover.

Various elements of the ecosystem are vulnerable to physical damage caused by direct use. The **grounding of a large vessel** can have significant and long-lasting environmental effects on a local area. As well as direct physical damage to the grounding site, toxic substances may be released including from antifouling paint and any cargo or oil spills. These can have damaging or lethal effects on marine life, significantly prolonging recovery times. Recognising the management and best practice arrangements in place, **groundings of small vessels** and the **physical damage of reef structure** caused by activities such as diving, snorkelling and anchoring are likely to cause only minor localised effects on the surrounding habitats.

Increasing use of the Region will increase the likelihood of impacts.

Physical damage to seafloor is mainly caused by trawling and, more locally, anchoring. Seafloor habitats and seabed plants and animals are vulnerable to trawling, which may remove or damage a substantial proportion of seabed plants and animals in intensely trawled areas, with some taking decades to recover.[318,319] However, few areas of the Region are trawled intensively, and overall habitat-level risks are generally low for seafloor habitats in lagoon areas.[312,319] Sea floor habitats including seagrass meadows are vulnerable to the chronic localised impact of ships anchoring.[320]

Both **large chemical spills** and **large oil spills** could have regional and long-lasting effects on the ecosystem, including physical smothering and persistent effects on the health, growth, reproduction, development and survival of a range of marine plants and animals.[321] The vulnerability of the ecosystem to the effects of **small spills** varies depending on the type of spill and the local environmental conditions. They can be toxic on a local scale.

The ecosystem is vulnerable to a number of threats associated with vessel use. Surface-breathing marine animals such as marine turtles, dugongs, dolphins and whales are typically affected by **vessel strikes**, often resulting in injury or death. **Waste discharged from vessels** increases nutrients in the water column, but this is likely to be only a small portion of the additional nutrients in the system, resulting in only minor effects. **Exotic species** introduced on vessels could have regional effects on the ecosystem — the nature of those effects would depend on the species introduced. Some species can be affected by **artificial light** around vessels, for example pelagic fishes.[322]

A range of wildlife is vulnerable to **marine debris**, particularly plastics. They can become entangled in the debris or ingest it, potentially leading to choking, starving or absorbing leached chemicals.[295,323,324,325,326] Plastic makes up about 90 per cent of the marine debris ingested by marine turtles in Queensland.[299]

Sound is extremely important to many marine animals, and increased **underwater noise** has been shown elsewhere to have a range of potential effects, including behavioural changes, hearing loss, physical injury and mortality.[327]

6.6.3 Vulnerability of heritage values to direct use

Indigenous heritage values and cultural practices as well as natural heritage values and world heritage attributes relating to Traditional Owners' interaction with the environment are severely affected by the declines in culturally significant species, partly attributable to past and present use of the Region. Examples of these species include dugongs, marine turtles, sea snakes, sharks, rays, some fish species, crayfish, oysters and clams. To varying degrees, these species are vulnerable to being injured or dying as **incidental catch** in fishing activities; direct extraction through commercial and recreational fishing; **illegal fishing and poaching**; **vessel strike on wildlife**; **wildlife disturbance**; and ingestion and entanglement in **marine debris**.

Indigenous heritage values are vulnerable to depletions in culturally significant species and incompatible uses.

Cultural practices, the continuation of many types of Indigenous heritage values, and world heritage attributes relating to Traditional Owners' interaction with the environment are vulnerable to increases in **incompatible use** in the Region, such as where other activities conflict with Traditional Owner cultural use of marine resources in the sea country areas where they express their native title rights.[328]

The lack of identification and management for many underwater wrecks and Indigenous sites of significance, story places and songlines makes them vulnerable to activities that cause **damage to reef structures, damage to the seafloor or modify coastal habitats**.

The aesthetic value of seascapes and islands may be diminished as a result of **marine debris** and **spills**.[329] Attributes such as tranquillity, solitude and remoteness are affected by **artificial light** and **noise pollution**[329], including that arising from vessel activity and in anchorage areas[320].

The vulnerability of those attributes that make up the world heritage property's outstanding universal value matches that described for the ecosystem (Section 6.6.2) and for Indigenous heritage values and aesthetics above.

6.6.4 Implications of direct use for regional communities

The economic and social components of the Great Barrier Reef are intrinsically linked to its ecosystem — the future of each depends on the future of the others.

For the Reef-dependent industries, their economic benefit is derived from the Region's natural resources, either through extraction of those resources or through tourism and recreation focused on its ecosystem and heritage values. Any future declines in the condition of those values are likely to have economic implications for those industries. As a result, they are particularly vulnerable to threats that affect the long-term health of the Region. For example, the tourism industry continues to be concerned about overall declines in the ecosystem and the potential loss of the Reef's world heritage status. Most recently, they have expressed particular concern about the effects of port development, including dredging and the disposal of dredge material[330].

Use of the Region maintains people's connections to it.

For other uses, such as ports and shipping, there is less likely to be a direct connection between them and the Region's values and they are therefore unlikely to be directly affected by changes in Reef condition. Their economic value is largely driven by factors external to the Region such as global demand for resources.

Most local residents visit the Region.[144] Use of the Region for recreation, traditional use of marine resources, fishing and commercial marine tourism is the way many of the social benefits, such as understanding and appreciation, enjoyment, personal connection and health benefits, are realised. Many individuals and communities maintain strong connections with the Reef, through culture, occupation or familiarity.[331] Aboriginal and Torres Strait Islander culture and connections are kept alive in large part by visiting and caring for their land and sea country.

If not properly managed, predicted increases in use of the Region may result in **incompatible uses** at particular sites becoming an emerging issue. For example, there are reports of incompatibility between the high density of ships in anchorage areas and fishing and tourism activities.[320]

If predicted increases in use are not well managed, instances of incompatible uses will rise.

6.7 Assessment summary — Factors influencing the Region'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. Regulation 116A(2)(e) of the *Great Barrier Reef Marine Park Regulations 1983* requires '… *an assessment of the factors influencing the current and projected future heritage values*…' of the Great Barrier Reef Region.

The assessment is based on four assessment criteria:

- impacts on ecological values
- impacts on heritage values
- impacts on economic values
- impacts on social values.

6.7.1 Impacts on ecological values

Outlook Report 2009: Assessment summary

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.

2009 Grade	Current summary and assessment components	Assessment grade and trend				Confidence	
		Very low impact	Low impact	High impact	Very high impact	Grade	Trends
🟧	**Impact on ecological values:** Climate change has already affected the Great Barrier Reef ecosystem. Its effects are compounding the ongoing impacts from land-based run-off and coastal development, particularly loads of sediments and nutrients entering the Region and the modification of supporting coastal habitats. Direct uses contribute to a range of impacts; most are localised. Economic and population growth will likely mean more use of the Region, increasing the likelihood of impacts. The combined influence of the four factors is concentrated in inshore central and southern areas.			🟧 ↑ ↑			
🟥	**Climate change:** Climate change is predicted to continue to have far-reaching consequences for the Reef ecosystem and over the next 50 years it is likely to significantly affect most components. Future predictions indicate sea level rises and temperature increases will continue, the pH of the ocean will gradually decline and weather will be more severe.				🟥 ↑ ↑	●	●
🟧	**Coastal development:** Modification of terrestrial habitats that support the Great Barrier Reef is likely to continue based on the projected changes in the catchment. Changes to coastal habitats and reductions in connectivity affect the Region's ecosystem.			🟧 ↑ ↑		●	●
🟧	**Land-based run-off:** Inshore areas are particularly at risk from poor water quality. Agricultural practices in the catchment are improving and there have been reductions in the nutrient, sediment and pesticide loads from the catchment entering the Region. There is likely to be a significant lag before water quality improvements are measured in the Region. Marine debris continues to affect the ecosystem — including species of conservation concern.			🟧 ↓ ↓		●	●
🟨	**Direct use:** Fishing continues to affect the Region's values such as through discarded catch; incidental catch of species of conservation concern; overfishing and illegal fishing. Increasing port activities directly affect local areas; uncertainty remains around ecosystem effects. Increasing regional populations and economic development will likely increase direct use and therefore the likelihood of impacts.		🟨 ↑ ↑			◐	◐

Grading statements

□ **Very low impact** Few or no impacts have been observed and accepted predictions indicate that future impacts on the Region's ecological 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 ecological values.

🟧 **High impact** Current and predicted future impacts are likely to significantly affect the Region's ecological 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 ecological values. Widespread and serious ecosystem effects likely within next 10–20 years.

Trend since 2009

↑ Increased
↔ Stable
↓ Decreased
— No consistent trend

Future trend

↑ Increasing
↔ Stable
↓ Decreasing
— No consistent trend

Confidence

● Adequate high-quality evidence and high level of consensus
◐ Limited evidence or limited consensus
○ Inferred, very limited evidence

6.7.2 Impacts on heritage values

Outlook Report 2009: Not assessed

2009 Grade	Current summary and assessment components	Assessment grade and trend				Confidence	
		Very low impact	Low impact	High impact	Very high impact	Grade	Trend
Not assessed	**Impact on heritage values:** Impacts on the ecosystem are reflected in declines in related heritage values, especially Indigenous heritage, natural heritage and world and national heritage values. Attributes of outstanding universal value relating to natural beauty, natural phenomena, ecological processes, and habitats and species are being affected. For built heritage, the threats from climate change and direct use are the most serious.			🟧 ↑			
Not assessed	**Climate change:** The vulnerability of the ecosystem to climate change flows through to dependent heritage values, especially the Reef's outstanding universal value, natural heritage values and Indigenous heritage values. Altered weather patterns and sea level rise increase the risks to built structures such as lightstations, shipwrecks and fish traps.				🟥 ↑	◐	◐
Not assessed	**Coastal development:** Modification of coastal areas affects the Reef's outstanding universal value, altering supporting habitats and connecting processes, and affecting scenic vistas. Coastal development has affected Indigenous heritage values. Unidentified nearshore historic heritage values are vulnerable to modification and reclamation of the coast, dredging and disposal of dredge material.			🟧 ↑		◐	◐
Not assessed	**Land-based run-off:** Many of the Region's heritage values, including its outstanding universal value, are vulnerable through the ecosystem effects of land-based run-off, especially in central and southern inshore areas. Water quality declines and marine debris are likely to be diminishing the Region's natural beauty. Increased sedimentation may be affecting underwater wrecks.			🟧 ↓		●	◐
Not assessed	**Direct use:** Uses such as fishing and ports are affecting some attributes that contribute to the outstanding universal value of the world heritage property. Heritage values are affected by physical damage and pollution as a result of direct use. Indigenous heritage values are especially vulnerable to depletions in culturally significant species and incompatible uses.		🟨 ↑			●	◐

Grading statements				Trend since 2009	Future trend
Very low impact Few or no impacts have been observed and accepted predictions indicate that future impacts on the Region's heritage 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 heritage values.	**High impact** Current and predicted future impacts are likely to significantly affect the Region's heritage values. Concern about serious effects on the Region's heritage values within next 20–50 years.	**Very high impact** Current and predicted future impacts are likely to irreversibly destroy much of the Region's heritage values. Widespread and serious effects on the Region's heritage values likely within next 10–20 years.	New assessment for this report; no trend provided	↑ Increasing ↔ Stable ↓ Decreasing − No consistent trend

Confidence

- ● Adequate high-quality evidence and high level of consensus
- ◐ Limited evidence or limited consensus
- ○ Inferred, very limited evidence

6.7.3 Impacts on economic values

Outlook Report 2009: Assessment summary

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.

2009 Grade	Current summary and assessment components	Assessment grade and trend				Confidence	
		Very low impact	Low impact	High impact	Very high impact	Grade	Trends
🟧	**Impact on economic values:** Changes to the Great Barrier Reef ecosystem have serious economic implications for Reef-dependent industries, such as tourism and fishing, and for adjacent communities. Perceptions about the health of the ecosystem affect its attractiveness for tourism and recreation. An increasing coastal population is likely to increase the economic value of direct uses.			🟧 ↑ ↑			
🟧	**Climate change:** Climate change effects on the ecosystem are expected to have major economic consequences for Reef-dependent industries.			🟧 ↑ ↑		◐	●
🟨	**Coastal development:** An increasing coastal population and improved coastal infrastructure is likely to increase the economic worth of uses in the Region. The loss of ecosystem services provided by coastal habitats will ultimately affect the value of Reef-dependent industries.		🟨 − −			◐	◐

6.7.3 Impacts on economic values *continued*

2009 Grade	Current summary and assessment components	Assessment grade and trend Very low impact	Low impact	High impact	Very high impact	Confidence Grade	Trends
🟧	**Land-based run-off:** Ecosystem declines from poor water quality, particularly in inshore areas, affect Reef-dependent industries. Outbreaks of crown-of-thorns starfish can affect the viability of tourism operations.			🟧 ↓ ⍗		◐	◐
🟨	**Direct use:** Direct use of the Region continues to be a significant contributor to regional and national economies. The future value of many uses depends on a healthy, intact ecosystem.	🟨 ↔ ⬄				●	◐

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.

Trend since 2009

- ↑ Increased
- ↔ Stable
- ↓ Decreased
- ▬ No consistent trend

Future trend

- ⍐ Increasing
- ⬄ Stable
- ⍗ Decreasing
- ⊟ No consistent trend

Confidence

- ● Adequate high-quality evidence and high level of consensus
- ◐ Limited evidence or limited consensus
- ○ Inferred, very limited evidence

6.7.4 Impacts on social values

Outlook Report 2009: Assessment summary
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.

2009 Grade	Current summary and assessment components	Assessment grade and trend Very low impact	Low impact	High impact	Very high impact	Confidence Grade	Trends
🟫	**Impact on social values:** Declining ecosystem condition, especially inshore adjacent to the developed coast, from the cumulative effects of many factors mean people's attachment to and enjoyment of the Region may lessen in the future. This may have flow-on effects on Reef-dependent industries. Predicted increasing use may mean more instances of incompatible use.		🟫 ↑ ⍐				
🟧	**Climate change:** Climate-related changes to the ecosystem could affect patterns of use of the Great Barrier Reef and visitor satisfaction. People's awareness of the potential effects of climate change is increasing their concern about the ecosystem. The vulnerability of Reef-dependent individuals and businesses depends on their ability to anticipate and adapt to change.			🟧 ↑ ⍐		◐	◐
🟫	**Coastal development:** Access to the Region improves through development of coastal infrastructure. Social benefits such as enjoyment, appreciation and understanding of the Reef's values depend on healthy coastal and marine ecosystems.		🟫 ↔ ⬄			◐	◐
🟫	**Land-based run-off:** The effects of land-based run-off on the ecosystem can influence social values such as the aesthetics, personal connection, enjoyment and appreciation.		🟫 ↓ ⍗			◐	◐
🟫	**Direct use:** The Great Barrier Reef continues to be valued well beyond its local communities, with strong national and international interest. Use of the Region maintains people's connections to it. If predicted increases in use are not well managed, instances of incompatible uses will rise.		🟫 ↔ ⬄			◐	◐

6.7.4 Impacts on social values *continued*

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 values. Widespread and serious effects on the Region's social values likely within next 10–20 years.

Trend since 2009	Future trend
↑ Increased	↑ Increasing
↔ Stable	↔ Stable
↓ Decreased	↓ Decreasing
▬ No consistent trend	▬ No consistent trend

Confidence	
●	Adequate high-quality evidence and high level of consensus
◐	Limited evidence or limited consensus
○	Inferred, very limited evidence

6.7.5 Overall summary of factors influencing the Region's values

The factors influencing the Region's ecosystem and its heritage values remain the same as the Outlook Report 2009, namely climate change, coastal development, land-based run-off and direct use of the Region. Understanding of their current and likely future effects has improved, especially for coastal development and land-based run-off.

The threats arising from these multiple factors, both those external to the Great Barrier Reef as well as within the Region, are having increasing and cumulative effects on the ecosystem as well as heritage, economic and social values. Coastal development and land-based run-off are having a high impact on ecological and heritage values. The influence of direct use activities within the Region is notable, but is assessed to be of lower impact overall. The projected, far-reaching, impacts from climate change are likely to ultimately overshadow the effects of other factors and uses. Addressing the other factors, which can be more directly managed, will improve the resilience of the Region's values to any future impacts of a changing climate.

Climate change is already affecting the Region's physical, ecological and social environment. Climate change will drive global changes in ocean pH and prominent weather events and characteristics such as temperature, cyclones, heavy rainfall, droughts, and prevailing winds. The global climate system is now warmer and moister than it was 50 years ago, and this influences the likelihood of significant weather events. Recent cyclones, hot spells and high rainfall events have demonstrated the capacity that ongoing changes to the Region's climate have to significantly affect ecosystem and heritage values. In addition, climate change has implications for all the other influencing factors and their trends into the future.

The continuing increasing trends in climate change variables means that it is likely to be an increasingly important factor in the Region. Addressing the other, more directly managed, factors influencing the Region's values will improve the resilience of these values to any future impacts of a changing climate.

Coastal development continues to be associated with modification and loss of coastal habitats and disruption to ecological connectivity. Additionally, while there have not been broadscale changes in land use patterns in recent years, the legacy effects of past land clearing and associated practices are still a significant influence on the Region. Activities related to resource extraction have continued to expand and, as a result, there has been major growth in port activity. Coastal development can provide social and economic benefits through improved infrastructure and ability for more people to experience the Region.

Sediments, nutrients, pesticides and other pollutants entering the Region in land-based run-off remain key issues for the Region. Valuable advances have been made in reducing contemporary inputs from diffuse agricultural sources. At a point-source scale, almost all major sewage treatment plants have been upgraded. The legacy of past land management practices continues to be an ongoing impact. Knowledge has increased around marine debris and its implications for the Region. Multiple stewardship programs and activities in the catchment and the Region are focused on monitoring and improving water quality and reducing the impacts of threats like marine debris.

A multitude of direct use activities occur in the Region. Most are likely to be having relatively minor effects on the Region's values at a Reef-wide scale. However, their contribution to cumulative effects can be significant. Fishing occurs across much of the Region. It affects both the species extracted and those that are discarded (particularly species of conservation concern). This results in flow-on effects for other levels in the food web and other parts of the ecosystem.

There is an increased understanding of the drivers of change in the use of the Great Barrier Reef catchment and Region. Many of these have positive and negative flow-on effects to the Region's values. There is also an increased recognition and understanding of social and economic values associated with the Region.

Continued population growth, driven in part by a strong economy, is predicted to lead to increased, mainly recreational, use of the Region. However this also brings challenges with increases in illegal activities and, the potential for people's enjoyment to be compromised by incompatible uses at popular sites. Conversely, an increase in recreational use is likely to drive positive economic effects in regional economies from the flow-on purchases associated with visiting the Reef.

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Existing protection and management

CHAPTER 7

'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*

'an assessment of the existing measures to protect and manage the heritage values...' of the Great Barrier Reef Region, Section 116A(2)(d) of the *Great Barrier Reef Marine Park Regulations 1983*

2014 Summary of assessment

Understanding of context	Context is assessed as the strongest management effectiveness element and trends are either stable or improving. Understanding of values, direct and indirect threats and stakeholders is generally strong. Understanding of cumulative and consequential impacts as well as condition and trend is improving and has been effectively documented through the Outlook Report and strategic assessment processes. In particular, tourism, defence activities, recreation, research activities and land-based run-off are well understood. This reflects a solid information and research base and a very mature understanding of the key values of the Region.	↑ Very good, Improved
Planning	Significant efforts have been made in planning for a number of topics such as biodiversity protection and recreation. Planning effectiveness has declined for climate change measures specific to the Region, principally as a result of changing policy and a lack of clarity about future directions. It has also declined for commercial marine tourism and research activities, largely because plans and policies have not been completed or updated. For coastal development, the fractured nature of the planning regime is problematic and recent changes have raised concerns. Planning effectiveness has improved for the management of land-based run-off and traditional use where the investment of resources is paying dividends. Lack of consistency across jurisdictions is the weakest aspect of planning.	↔ Good, Stable
Financial, staffing and information inputs	Adequacy of inputs is variable across management topics, being least effective for community benefits, coastal development and non-Indigenous heritage management. Poor understanding of heritage values is a problem for most issues and is among the worst performing criteria across the whole assessment. Availability of socioeconomic knowledge has improved. Substantial resources have been devoted to the topics of land-based run-off and traditional use. Secure resourcing is a significant ongoing problem for many management topics. In many cases the lack of adequate resources to advance planning and management is constraining the effectiveness of other aspects of management.	↔ Poor, Stable
Management systems and processes	Management processes are particularly strong for defence activities, shipping and management of land-based run-off. They are weakest for coastal development, community benefits and Indigenous heritage values. Addressing consequential and cumulative impacts, application of socioeconomic and Indigenous knowledge, and setting of targets to benchmark performance are problematic for most issues. Consideration of cumulative and consequential impacts has improved substantially. Stakeholder engagement and application of biophysical information are the strongest aspects of management across all issues.	↓ Good, Deteriorated
Delivery of outputs	Delivery of desired outputs was rated as effective or very effective for all topics except coastal development. It is strongest for commercial marine tourism, defence activities, research activities and land-based run-off, where there has been a noticeable improvement. The knowledge base of managing agencies and the community has consistently improved. While the majority of management programs are progressing satisfactorily, timeframes frequently slip and it is not yet clear that the programs are achieving all their desired objectives.	↔ Good, Stable
Achievement of outcomes	Achievement of desired outcomes is highly variable across the management topics. Objectives in relation to community understanding of issues and development of effective partnerships are being achieved. Performance in outcomes is especially strong for research activities, shipping and defence activities. Overall, the weakest performance was for climate change, then coastal development, land-based run-off and fishing. For land-based run-off, the continued poor outcomes for the Region are largely due to scale of the problem and lags within the natural system.	↓ Poor, Deteriorated

Full assessment summary: see Section 7.5

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Existing protection and management

7.1 Background

> **Outlook Report 2009:** Overall summary of existing protection and management
>
> 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).
>
> 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 as 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.

Protection and management of the Great Barrier Reef Region (the Region) is a partnership between many government agencies, stakeholders and community members, with activities both on the water and in the catchment. An understanding of the effectiveness of these activities is an important component in determining the likely resilience of the Region's ecosystem and heritage values, assessing the major risks that remain for the Great Barrier Reef and predicting its outlook.

The effectiveness of existing measures to protect and manage the Region's ecosystem was independently assessed in the Great Barrier Reef Outlook Report 2009.[1] A similar assessment by four independent reviewers has been undertaken for this report, with additional emphasis on the effectiveness of measures to protect and manage heritage values. The assessment considers the activities of all government agencies and other contributors that play a role in protection and management of the Region.

7.1.1 Roles and responsibilities

Protection and management responsibilities within the Region: Both the Australian and Queensland governments have direct legislative responsibilities within the Region (Figure 7.1). Under Australia's constitution, regulation of natural resource management and environment protection are primarily the responsibility of state governments — in this case, Queensland. However, the Great Barrier Reef and Australia's world and national heritage properties are protected through national regulation.

Both the Australian and Queensland governments have legislative responsibilities within the Region.

The *Great Barrier Reef Marine Park Act 1975* (the Act) establishes the Great Barrier Reef Marine Park Authority and governs its operations. The main object of the Act is to provide for the long-term protection and conservation of the environment, biodiversity and heritage values of the Great Barrier Reef Region. The Great Barrier Reef Marine Park Authority manages the Great Barrier Reef Marine Park (see Figure 1.1) in accordance with the Act. This Commonwealth marine protected area is complemented by the Queensland Great Barrier Reef Coast Marine Park in adjacent Queensland waters.

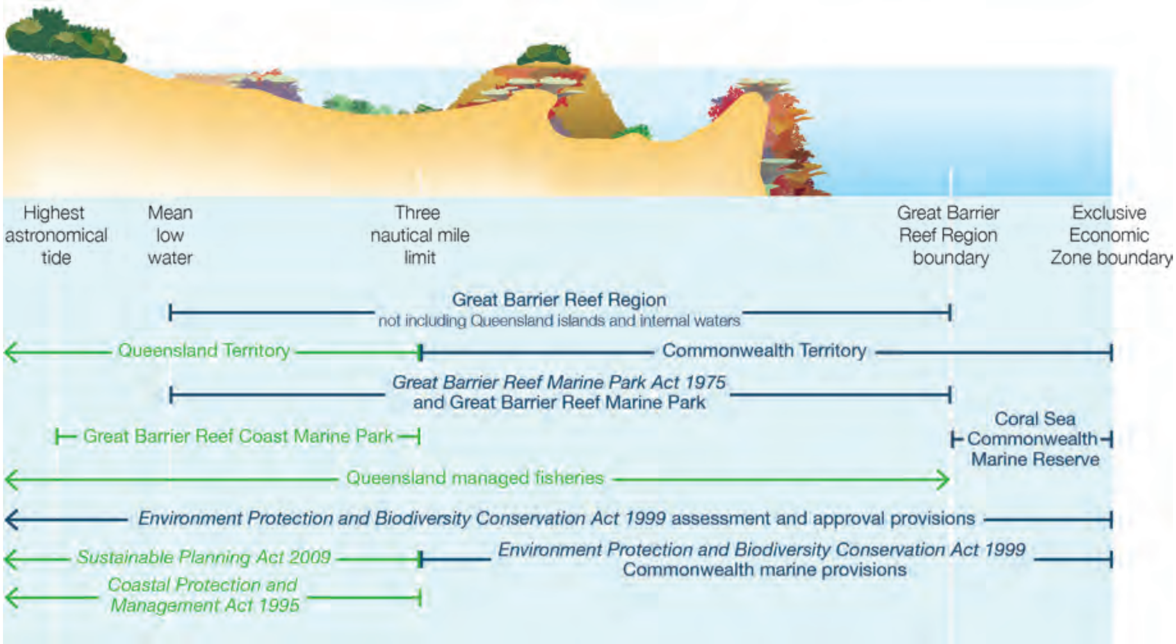


Figure 7.1 Jurisdictional boundaries
The Great Barrier Reef Region encompasses both Commonwealth and Queensland jurisdictions. Queensland territory extends from the land to the three nautical mile limit. An agreement to jointly manage marine parks and island national parks ensures integrated field management of both the Great Barrier Reef Marine Park and the adjacent Great Barrier Reef Coast Marine Park. Fisheries management, 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; however, its Commonwealth marine area provisions apply only in Commonwealth Territory.

The Australian and Queensland governments work in partnership to protect and manage the Region, formalised through the *Great Barrier Reef Intergovernmental Agreement 2009*. There is a close working relationship between the responsible government agencies, resulting in joint management on many issues within the Great Barrier Reef Marine Park, the adjacent Queensland Great Barrier Reef Coast Marine Park and Queensland island national parks.

Protection and management responsibilities outside the Region: Many of the threats to the Region's ecosystem and heritage values are the result of actions beyond its boundaries (such as climate change, 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.

The Australian Government has national and international responsibilities in relation to environment and heritage protection. Under the Environment Protection and Biodiversity Conservation Act 1999, it is responsible for regulating activities having or likely to have a significant impact on matters of national environmental significance (including the Great Barrier Reef Marine Park and world heritage properties), whether they are undertaken in or outside the Region. The Queensland Government is responsible for natural resource management and land use planning for Queensland's islands, coast and hinterland, including through the *Sustainable Planning Act 2009* and the *Coastal Protection and Management Act 1995*.

The Australian and Queensland governments work in partnership to manage the Region © Chris Jones

Partners in management: In addition to the Great Barrier Reef Marine Park Authority, many government agencies, Traditional Owners, stakeholders and individuals directly participate in protection and management activities within the Region and the adjacent catchment. For example:

- Within the Australian Government: the Department of the Environment is responsible for implementing the Environment Protection and Biodiversity Conservation Act; Border Protection Command provides aerial surveillance of the Region; and the Australian Institute of Marine Science undertakes research that supports management.
- Within the Queensland Government: the Queensland Parks and Wildlife Service is responsible for day-to-day field management; the Department of Environment and Heritage Protection is the lead agency on environmental management matters in intertidal areas, internal waters and the catchment; and Queensland Boating and Fisheries Patrol enforces fisheries, marine park and transport legislation.
- Local governments are responsible for local planning and development decisions and providing local roads, waste removal and water treatment in the catchment.
- Traditional Owners work to protect cultural and heritage values, conserve biodiversity and enhance the resilience of the Great Barrier Reef.
- Industry groups, regional natural resource management bodies, research institutions, schools, community groups and individuals are involved in presenting the world heritage values of the Region, understanding the Region's values, minimising impacts, addressing threats and improving outcomes.

Many government agencies, Traditional Owners, industries, researchers and community groups contribute to protection and management.

In addition, the Great Barrier Reef Marine Park Authority receives advice on protection and management of the Great Barrier Reef Marine Park from 12 Local Marine Advisory Committees and issues-based Reef Advisory Committees and places a strong emphasis on community engagement, consultation and participation. The Queensland Government maintains structured advisory arrangements for tourism management through its State-wide Tourism Industry Forum.

7.1.2 Focus of management

Activities to protect and manage the Great Barrier Reef are focused on 14 broad management topics:

Managing direct use

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

Managing external factors

- climate change
- coastal development
- land-based run-off.

Managing to protect the Region's values

- biodiversity values
- heritage values
- community benefits of the environment.

These topics are the basis of the assessment of existing measures to protect and manage the Region's ecosystem and its heritage values.

The majority of management topics examined in the Outlook Report 2009 are repeated in this report. The amendments are: ports and shipping are separated to reflect the differences in both their management arrangements and their potential effects on the Region; and the topic of community benefits is added. Community benefits include aspects such as employment and income, and less tangible attributes such as understanding, appreciation, enjoyment, personal connection, health benefits and access to the Reef.

The effectiveness of managing education activities was not assessed by the independent assessors as it is only a small component of the overall management task.

Incidents such as this grounding off Lady Elliot Island trigger a multi-agency response

7.1.3 Management approaches and tools

In protecting and managing the Region, three main management approaches are used:

- Environmental regulation: management tools such as regulations, zoning plans, management plans, permits and licences, and compliance are used to establish the statutory arrangements and environmental standards necessary to protect and manage the Reef.
- Engagement: managing agencies work with Traditional Owners, the community, business, industry and local government to influence best practice and encourage actions that will help secure the future health of the Reef.
- Knowledge, integration and innovation: management is based on the best available science as well as drawing on traditional ecological knowledge and information from the wider community, and is informed by the results of ongoing monitoring.

Each of these approaches is explicitly assessed in Section 7.4. They were not assessed in the Outlook Report 2009.

A wide range of tools is employed to implement these approaches:

- Acts and Regulations
- zoning plans
- management plans
- permits and licences (including environmental impact assessment and measures to avoid, mitigate and offset impacts)
- Traditional Owner agreements
- compliance
- site infrastructure
- fees and charges
- policy (including strategies, policies, position statements, site management arrangements and guidelines)
- partnerships
- stewardship and best practice
- education and community awareness
- research and monitoring
- reporting.

A wide range of tools is employed in protecting and managing the Region.

Each management tool is employed to address a number of topics and a combination of tools is applied to each topic (Table 7.1). In the assessment, all of the relevant tools are considered for each management topic.

Table 7.1 Management tools used in addressing the broad management topics

	Direct uses								External factors			Values		
Management tools	Commercial marine tourism	Defence activities	Fishing	Ports	Recreation (other than fishing)	Research and educational activities	Shipping	Traditional use of marine resources	Climate change	Coastal development	Land-based run-off	Biodiversity values	Heritage values	Community benefits of the environment
Acts and Regulations	●	●	●	●	●	●	●	●		●	●	●	●	●
Zoning plans	●	●	●	●	●	●	●	●		●	●	●	●	●
Management plans	●	●	●	●	●	●	●	●				●	●	●
Permits and licences	●		●	●	●	●	●	●		●	●	●	●	●
Traditional Owner agreements								●				●	●	●
Compliance	●	●	●	●	●	●	●	●		●	●	●	●	●
Site infrastructure	●		●	●	●	●	●					●	●	●
Fees and charges	●		●	●		●	●				●			
Policy	●	●	●	●	●	●	●	●	●	●	●	●	●	
Partnerships	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Stewardship and best practice	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Education and community awareness	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Research and monitoring	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Reporting	●	●	●	●	●	●	●	●	●	●	●	●	●	●

7.2 Assessing protection and management measures

In order to ensure the independence of the assessment of existing measures to protect and manage the Region's ecosystem and heritage values, the Great Barrier Reef Marine Park Authority commissioned four external independent assessors to jointly undertake the assessment. These assessors have expertise in protected area management, defence, ports and shipping, monitoring and evaluation, public policy and governance. Their report[2] is summarised in Sections 7.3 to 7.5 of this chapter.

The effectiveness of protection and management measures was independently assessed.

7.2.1 Scope

As with the Outlook Report 2009, the assessment includes the activities of all Australian and Queensland government agencies and other partners that contribute to protection and management of the Region. The scope is therefore much broader than just the Great Barrier Reef Marine Park Authority.

Management actions undertaken both inside and outside the Region are examined to the extent that they influence protection and management of the Region's ecosystem and heritage values. In relation to the global issue of climate change, the assessment considers measures undertaken specifically to protect and manage the Region and does not consider broader state, national and global initiatives. While it is recognised that activities and management arrangements beyond Australia affect some migratory species, these are beyond the scope of this report.

7.2.2 Assessment method

A structured framework guided the assessment of effectiveness.

So that the assessment is comparable with that reported in 2009, the independent assessment again followed the framework for evaluating the effectiveness of 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 7.2).

The independent assessment of the effectiveness of existing protection and management measures examined the six elements of the management cycle for each management topic outlined in Section 7.1.2 above. Each topic was assessed independent of the others.

For each management topic, the independent assessors used a series of indicators to assess effectiveness at each stage of the management cycle (Appendix 4). The indicators varied slightly from those in the Outlook Report 2009. Some were refined based on the experience of that and subsequent assessments; some were deleted because they were no longer relevant or had proved difficult to reliably assess.

Based on the results of the assessment of each management topic, the independent assessors also provided a summary of effectiveness for each of the three broad management approaches (environmental regulation, engagement, and knowledge, integration and innovation).

Figure 7.2 Framework for assessing management effectiveness of protected areas
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. Source: Adapted from Hockings *et al.* 2006[3]

7.2.3 Information used

Information relevant to assessing performance against each of the indicators was assembled by both Australian and Queensland government agencies and provided to the independent assessors. They also sought additional information from relevant research papers and other source documents.

The assessment was based on documentation available and advice provided before the end of December 2013. Where necessary, information has been updated after this date, but this has not been comprehensive.

7.2.4 Scale and complexity

The assessment of effectiveness for each management topic has not been weighted to take into account differences in scale and complexity between topics (Table 7.2).

Table 7.2 Scale and complexity of management topics

Management topic	Scale	Complexity		
		Social	Biophysical	Jurisdictional
Managing direct use				
Commercial marine tourism	Region-wide but variable in intensity	Major	Moderate	Moderate
Defence activities	Limited in area and duration	Minor	Minor	Minor
Fishing	Region-wide but variable in intensity	Major	Major	Moderate
Ports	Concentrated around ports	Major	Moderate	Major
Recreation (not including fishing)	Region-wide but variable in intensity	Major	Moderate	Moderate
Research activities	Region-wide but limited in intensity	Minor	Moderate	Minor
Shipping	Concentrated around shipping lanes	Moderate	Moderate	Moderate
Traditional use of marine resources	Region-wide but variable in intensity	Major	Moderate	Moderate
Managing external factors				
Climate change	Region-wide	Major	Major	Major
Coastal development	Region-wide, limited to coastal catchment areas and mainly inshore waters	Major	Major	Major
Land-based run-off	Great Barrier Reef catchment and mainly inshore waters	Major	Major	Major
Managing to protect the Region's values				
Biodiversity values	Region-wide	Minor	Major	Moderate
Heritage values	Region-wide	Major	Moderate	Moderate
Community benefits of the environment	Region-wide	Major	Moderate	Minor

There is wide variation in the scale and complexity of management topics.

7.3 Assessment of existing protection and management measures

The following assessment of existing measures to protect and manage the Region's ecosystem and heritage values is a summary of an independent analysis by four independent expert assessors.

The full report of the independent assessors[2] is available online at **www.gbrmpa.gov.au.**

Managing direct use

7.3.1 Commercial marine tourism

Tourism within the Region is recognised by managers as one of its most significant uses and a key mechanism for presenting its values to Australian and international visitors. Tourism is also acknowledged to be a major driver for economic growth and employment for coastal Queensland.

Sound governance and industry partnerships are in place to address tourism issues.

The mutual understanding between managers, tourism operators and the conservation sector on the Reef's values relevant to tourism was improved as part of the process to recognise it as a 'national landscape'[14]. Reef tourism continues to perform well in terms of both visitor satisfaction and economic benefit.

There are sound governance and partnership arrangements for managing tourism, with a mix of tools employed. Consistency across jurisdictions is helped by joint permitting and assessment processes, although changes to Queensland Government policy have introduced some incompatibilities. A key issue is the complexity of the management arrangements and the level of understanding required of operators. Overall outcomes in relation to commercial marine tourism would likely be improved through simplification and alignment of management arrangements. There is no permit compliance program — although non-compliance is unlikely to be significantly threatening the Region's values.

An online system for the Environmental Management Charge, an online bookings system and improvements in permits management have increased user accessibility as well as improving understanding of the implications of latent capacity and trends in use. Ageing and poorly maintained tourism infrastructure is an emerging issue; an audit and compliance plan is being developed and relevant policy updated.

Planning has not proactively addressed emerging trends and opportunities as effectively as it might. While plans of management are in place for intensively-used areas, planning capability and the lack of a schedule of regular reviews affect the currency and consistency of plans. Although under development, an overarching strategy to guide tourism management identified as lacking in the Outlook Report 2009 is still to be finalised, and site planning has not expanded to areas where use is increasing. Policies covering many aspects of tourism are outdated.

The Great Barrier Reef Marine Park Authority continues to have high levels of skills related to marine tourism management and impact assessment, and continues to receive expert advice from its advisory committees. There has been a general decline in the delivery of interpretation about the Region and its values by the tourism industry, due mainly to difficulties in recruiting suitable staff and reductions in training opportunities.

Effectiveness of tourism management has declined as emphasis has shifted to emerging issues.

Reef health monitoring information provided by tourism operators through the Great Barrier Reef Marine Park Authority's Eye on the Reef program improves the information available for decision making. Monitoring information is better integrated, and the program has a user-friendly data portal and online training. Government agencies, scientists and the tourism industry are collaborating closely in addressing the threat of crown-of-thorns starfish outbreaks, especially at sites of high tourism value. The number of operators participating in the partnership High Standard Tourism program continues to grow, with the majority of tourists visiting the Reef on an independently certified high standard operator.

To some extent, successes in managing tourism have meant that management emphasis has shifted from it to other higher risk issues. This is reflected in a reduction of the management effectiveness grades relating to planning and management processes and a declining trend in the grades for management inputs and outputs.

7.3.2 Defence activities

Activities undertaken by the Department of Defence in the Region continue to be managed effectively with close cooperation clearly evident between the Department of Defence, Great Barrier Reef Marine Park Authority and other agencies. The Department of Defence recognises the area's world heritage status and the pressures it is facing, and is generally implementing best practice environmental management.

There is a management agreement between the Great Barrier Reef Marine Park Authority and the Department of Defence on implementation of a strategic environmental assessment of defence activities in the Great Barrier Reef Marine Park.[5] Strategic documents, policies and regular meetings facilitate implementation of the agreement and ensure a consistent approach with other management agencies.

Defence training exercise, Shoalwater Bay in the south of the Region

A key factor in achieving the evident high standard of management is that professional expertise, with access to appropriate levels of funding (and other management resources), has been made available to support defence activities in the Region and the adjacent defence training areas.

Training exercises include good performance monitoring, debriefs and post-exercise monitoring. The identification of clear environmental performance indicators in relation to training exercises, particularly those related to addressing cumulative impacts, remains a challenge. The adoption of new training activities and platforms, and changing patterns and intensities of training activities, are likely to present new environmental management challenges, especially in managing their cumulative impacts.

Defence activities continue to be managed very effectively with close cooperation between agencies.

There is emerging understanding of the unexploded ordnance, explosive ordnance waste, and the wide range of dumped war materials present in the Great Barrier Reef, particularly from World War II and immediately after. The Department of Defence implements Australian Government policy on unexploded ordnance and gathers and disseminates information to assist with the safe management of land and sea areas that may be subject to contamination. Not all sites in the Region are known or documented and there is no overall plan for monitoring or remediating unexploded ordnance in the Region. While the explosive risks are likely to be low and the incident response mechanism is generally excellent, the management framework and policies to address these legacy issues is dated and well below contemporary best practice for dealing with contamination by hazardous materials.

Adequate biophysical information within defence training areas continues to be available for decision making, including through hydrographic and ecological surveys. The Department of Defence undertakes community engagement for major exercises and has environmental advisory committees for its training areas.

A systematic approach generally ensures that statutory and planning timeframes are routinely met and results are reported by the Department of Defence in a timely manner. While Authority staff have an appropriate mix of skills to fulfil their statutory responsibilities for defence activities, the liaison and monitoring work is undertaken as a relatively low priority by a small number of Great Barrier Reef Marine Park Authority staff.

Defence training activities continue to be effectively undertaken in the Region. Any impacts are localised and short term, with any incidents well managed.

7.3.3 Fishing

Fishing is the principal extractive use of the Great Barrier Reef. Sustainable recreational, charter and commercial fisheries in the Region depend on a healthy Reef ecosystem.

Management of fishing and the aquatic environment on which it relies is shared between the Australian and Queensland governments, principally through Queensland's regulation, monitoring, compliance and education programs which include licensing commercial fishing, closures, gear and catch limits; and the programs of the Great Barrier Reef Marine Park Authority which include zoning, regulations, some permitting and stewardship programs. There are inconsistencies between state and Commonwealth management arrangements, for example some closure and apparatus requirements. The management arrangements for most commercial fisheries in the Region are accredited against national sustainability guidelines under the Environment Protection and Biodiversity Conservation Act. All accreditations in the Region are subject to conditions and recommendations.

Understanding of fishing and its impacts has improved; however, outcomes remain poor.

In general, the activities and programs relating to fishing have progressed in accordance with planned work programs. Several major management initiatives have been progressed, for example the rollout of the $9 million buyout in the net fishery (which as at December 2013 had removed 69 large mesh net symbols). In addition research studies, monitoring, extension work on bycatch reduction and reviews such as the trawl plan have informed management. However, actual changes to protect values and improve practices from these initiatives are more limited.

The achievement of outcomes presents ongoing challenges for fisheries management. Almost all fisheries sectors demonstrate varying degrees of progress towards desired biodiversity outcomes and better sustainability outcomes, but this is undermined by illegal fishing activities.

As identified in the Outlook Report 2009, there is a good understanding of the retained commercial catch. Key indicator fish species are monitored and assessed annually using information from monitoring and research. Ecosystem effects and cumulative impacts are poorly understood. Understanding of the risks associated with the East Coast Otter Trawl Fishery in the Great Barrier Reef has been improved through a comprehensive ecological risk assessment. The Great Barrier Reef Marine Park Authority has completed vulnerability assessments for two fisheries species.[6,7]

The Queensland Government annually identifies strategic and operational information needs for fisheries management, informed by annual status assessments of stocks, research findings and community concerns. However, the stock status of only 29 of the 65 fisheries resources harvested on the east coast of Queensland are defined. The remainder are classified as either uncertain or undefined because there is insufficient information available to make an assessment.

While there are specific programs to collect fisheries information, such as biological monitoring, recreational surveys and analysis of fisheries logbooks, they are often limited in scope and there is a lack of publicly available information on some. Anecdotal evidence suggests that interactions with ‘species of conservation interest’ are often not reported. Vessel monitoring systems are only in place for selected fisheries such as the East Coast Otter Trawl Fishery.

The ways in which fisheries interact with non-target species are understood, but remain largely unquantified. There are regulations aimed at minimising or preventing interactions. Limits on participation and gear restrictions are used to address remaining risks and unknown interactions. Protection of dugong from commercial netting in areas such as Bowling Green Bay has improved.

Ecosystem effects and cumulative impacts of recreational fishing are less well understood. In this sector, local depletion, particularly of some inshore species, is of concern in some areas.

Illegal fishing is considered one of the greatest risks to the environmental sustainability of fishing activities in the Region. Compliance activities, undertaken by the Queensland Boating and Fisheries Patrol, Border Protection Command and the Marine Parks joint Field Management Program, play a significant role in managing the impacts of fishing.

The resources available to agencies for the management of fishing have declined since 2009. For example, staffing resources in the Queensland Department of Agriculture, Fisheries and Forestry have declined by over one-third since 2009 and funding for the Field Management Program, which is responsible for many of the compliance activities, has been static since 2008 and declined in real terms.

Regionally based liaison and regular meetings with industry representatives aid communication and help identify and address issues. Stewardship among commercial fishers is promoted through the Great Barrier Reef Marine Park Authority’s pilot Reef Guardian Fishers program which, as at December 2013, involved nine operations and up to 50 fishing vessels.

7.3.4 Ports

In this assessment, the topic of ‘ports’ encompasses all aspects of the development, operation and maintenance of ports, with the exception of ship movements. It includes construction and maintenance of port facilities and navigational equipment, dredging, dredge material disposal, movement of harbour support vessels and the declaration and siting of anchorages (see Figure 5.23 for the location of anchorages). The assessment is confined to those aspects of the operation and management of Great Barrier Reef ports pertinent to the Region’s ecosystem and its heritage values.

There are 12 Great Barrier Reef ports, managed by four individual port authorities, all of which are Queensland Government-owned corporations. Of these, eight are located at least partly in the Region: Quintell Beach, Cape Flattery, Cooktown, Lucinda, Townsville, Abbot Point, Mackay and Hay Point.

Individual Great Barrier Reef ports are assessed as generally well managed, although there have been instances of shortfalls in planning and development programs. It is recognised that planning for future port developments could be improved. Effective implementation of the Queensland Government’s *Queensland Ports Strategy*, combined with its statutory ports master planning processes, should improve this situation.

Ports are generally well managed; there has been a lack of coordinated planning and guidance.

The ways in which ports and port activities threaten or influence the Region’s ecosystem and its heritage values are not clearly understood. For example, there remains uncertainty about the effects of resuspended dredge material on the Region’s values. The outcomes of recent modelling suggest resuspended material could move over greater distances than previously assumed, but there is limited consensus on the implications for the Region.

Stronger coordination of environmental monitoring, reporting, and research and evaluation within and between ports would improve understanding of their combined effects and influences on the Region’s ecosystem and its heritage values. Monitoring programs are also not sufficient to indicate new or emerging threats, such as a significant deterioration in water quality or the incidence of invasive marine species.

There is a lack of clear guidelines and management targets for the guidance of port developers and operators and the associated regulatory authorities addressing the operation of ports in relation to the protection and management of the Region’s ecosystem and its heritage values.

Port of Hay Point © *Susan Sobtzick*

Port planning in the recent past has appeared somewhat *ad hoc*. The significantly elevated number of port development proposals in the Region has accentuated concerns, both in Australia and internationally, about the likely future impacts of ports and port activities on the Region. Although some of the proposed port developments had the potential to threaten the Region's ecological processes and integrity, it is pertinent to recognise that to date port developments have not resulted in any significant, widespread deterioration of the Region. Some localised effects are recognised, for example at dredging and marine disposal sites.

7.3.5 Recreation (not including fishing)

Responsibility for managing 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 National Parks, Recreation, Sport and Racing, and Maritime Safety Queensland.

Recreation in the Region is managed through a variety of tools and coordination between relevant agencies in enforcing marine parks management arrangements is high. Some products and services such as maps and brochures are jointly prepared and presented. The diffuse nature of recreation means that the management arrangements do not provide certainty regarding where uses may occur and where any impacts are likely to be acceptable.

Substantial increases in the numbers of visits made by recreational users and shifts in the popularity of activities have been documented.[8] The results of the Social and Economic Long-term Monitoring Program are beginning to improve understanding of recreational use in the Region, including users' values and activities.

The lack of an overarching document to guide planning for recreational use was identified in the Outlook Report 2009 and has been addressed by the Great Barrier Marine Park Authority through subsequent preparation of a *Recreation Management Strategy for the Great Barrier Reef Marine Park*[9]. The strategy is designed to provide an overarching framework for the management of recreation in a coordinated manner and to inform the public of the management approach. The values that attract large numbers of visitors are well documented in the strategy, the threats and risks to those values are clearly articulated, and the management tools are identified. The major risks and threats and the avenues to reduce them are assessed; however, while cumulative impacts are recognised as an issue, their management is not specifically addressed. The strategy does not include any timeframes or targets to meet its objectives, making it difficult to assess achievement of outcomes.

An overarching recreation management strategy has improved understanding and coordination.

Development and implementation of the recreation management strategy is identified in the Great Barrier Reef Marine Park Authority's strategic plan, and resources are allocated in line with the objectives. A decrease in funding in real terms for the joint Field Management Program has focused recreation-related activities on compliance, interpretation and infrastructure maintenance.

Stakeholder engagement remains strong through advisory committees and the engagement activities of Great Barrier Reef Marine Park Authority staff, especially those in the regional offices. However, the diversity and informality inherent in the sector presents ongoing challenges to engagement.

7.3.6 Research activities

This evaluation of the effectiveness of management in relation to research activities concentrates on the direct management of research activities in the Region. The wider questions of the availability and application of knowledge gained from scientific research are separately considered under the other management topics.

There are robust governance arrangements in place to manage research on the Reef and research activities are generally considered to be environmentally sustainable.

There is strong collaboration in research management; improvements are slow.

The Great Barrier Reef Marine Park Authority and relevant Queensland agencies jointly manage research activities within the Region, including extractive and observational research. Permits for specific research projects and accreditation of partner research institutions are the principal means of managing potential impacts. There is stakeholder and local community engagement concerning proposed activities, as necessary, and research proposals with the potential to affect Indigenous values are referred to the relevant Indigenous liaison staff. There is limited compliance auditing of research permits.

Direct risks are recognised but potential cumulative impacts are unclear and warrant more focused attention. Specific management arrangements are in place to assist with the effective management of research in scientific research zones — where research is concentrated and cumulative impacts are most likely.

The assessment in the Outlook Report 2009 concluded that management of research in the Reef was moving towards desired outcomes. The foreshadowed database to manage permitted use information remains under development and it is not yet possible to use it for analyses. In addition, there is limited capacity to contribute to the formulation and review of regulations, plans and policies. For example, the policy on managing scientific research has not been reviewed since its introduction in 2004 and the sampling limits for limited impact research in the Great Barrier Reef Marine Park Regulations have not been reviewed since their introduction in the same year. As a result, management effectiveness grades for planning, inputs and processes have declined from effective to mostly effective.

There is increasing emphasis on managing research partnerships and collaborations that are delivering benefits to Great Barrier Reef management. The Great Barrier Reef Marine Park Authority's *Scientific information needs for the management of the Great Barrier Reef Marine Park 2009–2014*[10] identifies key information needed to better inform management of the area.

The Great Barrier Reef Marine Park Authority has very successful and effective relationships with the research community regarding management of research activities, demonstrated by the accreditation process and strong partnerships with research institutions.

7.3.7 Shipping

In this assessment, the topic of 'shipping' encompasses the movement and operation of ships, including ships travelling to, from and between ports in the Region, and those transiting through the Region. It also includes ship loading and unloading, ship anchoring and the activities of ships while at anchor (for example discharge of ballast water or effluent).

Shipping is generally well regulated and well managed; future risks are being addressed.

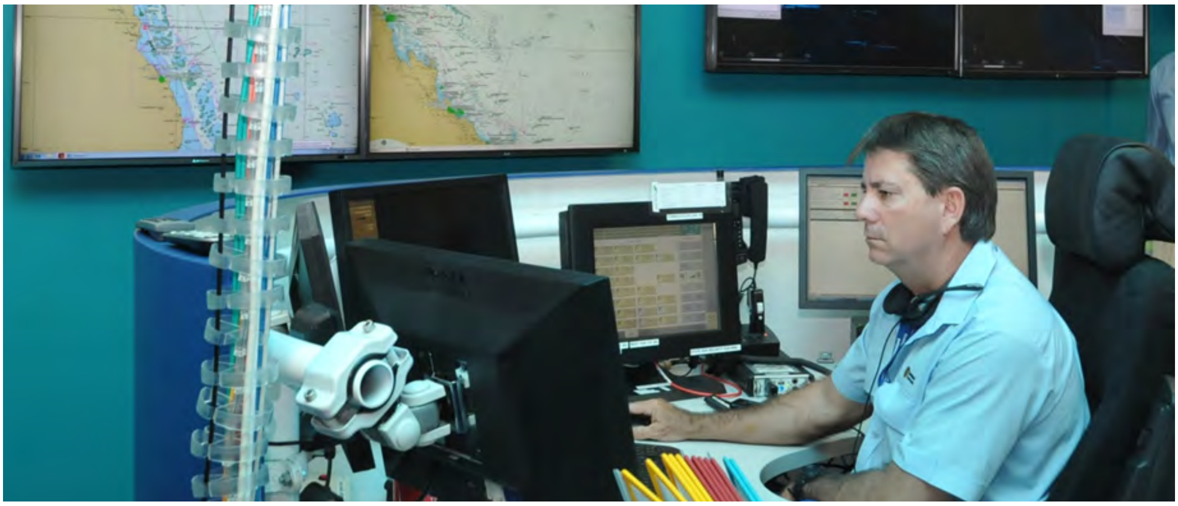
Shipping within the Region is generally well regulated and well managed. In comparison with other, often busier, shipping areas globally, there is an extensive suite of control, risk reduction and risk response measures applying to shipping in the Region. Although shipping incidents, such as loss of propulsion and navigation error, will inevitably occur, both the incidence and the potential consequences are attenuated by improvements in technology, ship design, management arrangements and safety requirements. Examples include protected fuel tanks, electronic aids to navigation, the Great Barrier Reef and Torres Strait Vessel Traffic Service (REEFVTS), port state control inspections and ship vetting. Combined, these measures reduce the risk of shipping incidents, despite increase in shipping activity.

The draft North-East Shipping Management Plan[11] jointly developed by a number of Australian and Queensland government agencies is an example of control and emergency response arrangements anticipating and pre-empting changes in shipping activity levels and risk profiles — a critical aspect of shipping management.

There are management arrangements in place to address chronic, low-level effects, although some are not comprehensively considered. Examples include the cumulative effects of leaching or loss of antifouling paints, wake and turbulence effects, and possibly altered light and underwater noise regimes. Impacts of shipping on aesthetic values, especially in remote areas, are an emerging issue.

The agencies responsible for managing shipping in the Region are generally well resourced to undertake the required tasks. There are well-coordinated initial response and clean-up arrangements in the case of an incident, as demonstrated in the response to the grounding of the *Shen Neng I* on Douglas Shoal in 2010. However, these arrangements need to be regularly reviewed and resources allocated as necessary in relation to changing risks. Aspects of shipping-related management considered to be under-resourced include restoration and rehabilitation of damaged areas following groundings and control, surveillance and monitoring for introduced species.

While not a primary managing agency for shipping, the Great Barrier Reef Marine Park Authority is a critical partner in shipping management arrangements in the Region with a focus on ensuring shipping operations are sustainable and consistent with management objectives. However, its objectives and implementation plans with regard to shipping have not been clearly articulated — if clearly documented this would help inform risk-based management and the optimal allocation of resources.



The Great Barrier Reef and Torres Strait Vessel Traffic Service facility in Townsville

7.3.8 Traditional use of marine resources

Traditional use of marine resources in the Region is primarily managed through Traditional Use of Marine Resources Agreements (TUMRAs) — formal agreements of Traditional Owner groups that are jointly accredited by the Australian and Queensland governments. These agreements promote sustainable use of threatened species such as dugongs and green turtles, as well as other species and habitats. Aspiration statements, clear objectives and implementation plans are part of each TUMRA.

As at April 2014, there were seven TUMRAs and one Indigenous Land Use Agreement which, combined, cover about 13 per cent of the Great Barrier Reef, engaging 14 Traditional Owner groups. One TUMRA has lapsed since the Outlook Report 2009.

Values relevant to traditional use of marine resources have been articulated in the draft *Great Barrier Reef Region Strategic Assessment Report*[12] and the *Biodiversity Conservation Strategy 2013*[13] and knowledge of the condition and trend of culturally important species such as dugongs and marine turtles has improved with vulnerability assessments[14]. Information on direct, indirect and cumulative impacts associated with traditional use is not widely available and therefore not well understood nor considered in management of the Region. However, any impacts attributable to traditional use of marine resources undertaken according to customs and traditions are considered to have only very minor effects.

The Australian Government Reef Programme Land and Sea Country Indigenous Partnership Program includes a program for the development and support of TUMRAs. It has engaged with over 80 per cent of the Region's Traditional Owner groups and achieved its aims and objectives over the past five years.

There is strong cooperative management of traditional use of marine resources; outcomes have improved with improved planning and inputs.

The pace of negotiation and implementation of TUMRAs is driven largely by Traditional Owners and their local capacity. Although dedicated funding has been provided by the Australian Government, there remains limited capacity within managing agencies to deal simultaneously with development of multiple TUMRAs.

Ascertaining Traditional Owners who can speak for their country can be difficult. One of the benefits in developing TUMRAs is that the relationship between sea country and a Traditional Owner group is identified and documented as part of the process. The effectiveness of engagement of broader stakeholders and local communities is highly variable.

Many of the staff working in this area are Indigenous, however developing the expertise of all managing agency staff is critical. The knowledge base in agencies is improving through the development of information management systems. High levels of sensitivity about the collection, storage and accessibility of traditional knowledge continue. There is still limited capacity to gather relevant data, especially related to socioeconomic drivers and traditional knowledge where this has been lost from the community.

Managing external factors

7.3.9 Climate change

This assessment considers the topic of climate change in relation to proactive and adaptive management measures undertaken specifically to protect and manage the Great Barrier Reef. Any broader state, national and global initiatives to address climate change, including mitigation and adaptation activities, are not considered. Assessing the overall effectiveness of the Reef-specific activities is challenging, as the ultimate outcomes for the Region's values depend heavily on the effectiveness of broader initiatives.

There is sound Region-scale management for climate change; management focus has declined on a broader scale.

The Great Barrier Reef Marine Park Authority has the major role in facilitating awareness of the impacts from climate change and extreme weather in the Region and in building the resilience of its ecosystem. It has an advisory role to other Australian and Queensland government agencies, and makes a significant contribution to the development of international best practice around coral reef management under a changing climate.

A number of management initiatives contribute to offsetting the impacts of climate change by reducing risks from other stressors. The Great Barrier Reef Marine Park Authority provides adaptation resources to help minimise the vulnerability of coastal communities and Reef-dependent industries while also increasing their capacity to collaborate in building ecosystem resilience to climate change.

Through implementation of the *Great Barrier Reef Climate Change Action Plan 2007–2012*[15], strategies that could help give the Great Barrier Reef the best chance of coping with a changing climate were identified and tested. The 2012 *Review of the Climate Change Action Plan 2007–2012*[16] concluded that the work undertaken under the plan had placed the Great Barrier Reef Marine Park Authority at the leading edge of efforts to understand, test and implement adaptation options for the Great Barrier Reef. Based on the review outcomes, future actions of the Authority and its partners are set out in the *Climate Change Adaptation Strategy and Action Plan 2012–2017*[17].

The managing agencies' planning initiatives are focused on enhancing ecological, socio-economic and management systems to adapt to change in ecological and social variables. Within the Great Barrier Reef Marine Park Authority, there is specialist expertise to coordinate efforts and facilitate national, regional and international collaboration and climate change considerations have been incorporated into many areas. There is a risk that changes in staffing and funding arrangements in 2014 will dilute attention to climate change issues. The loss of staff and associated research and management resources within the Queensland Government contributed to a decline in the assessment of the effectiveness of inputs for this topic.

Vulnerability assessments continue to provide good contextual information and specific threats have been identified. While direct and indirect impacts are understood by managers, many knowledge gaps remain. Work continues on identifying gaps in biophysical information, and socio-economic implications are being addressed through the Social and Economic Long-term Monitoring Program. Climate change work has been the catalyst for improvements in understanding and consideration of consequential and cumulative impacts on the Region's values. Efforts continue, including work with Traditional Owners, to apply available traditional knowledge to climate change considerations.

Community engagement relating to climate change continues through initiatives such as the Eye on the Reef program and the Reef Guardian program, and implementation of the climate change action plan contributes substantially to strengthened partnerships with tourism and fishing sectors.

The planned and systematic approach of the Great Barrier Reef Marine Park Authority in relation to climate change gives confidence it has been doing all that might be reasonably expected to reduce its effects in the Region. However, in spite of its good systems and processes, the long-term trend for the Region is still poor and the extent to which specific initiatives can effectively address particular problems will only become clear over time.

7.3.10 Coastal development

The topic of coastal development includes management of activities undertaken within the Great Barrier Reef catchment that affect the Region. Although part of this broad topic, the management of ports in and adjacent to the Region has been considered separately in Section 7.3.4. The management of land-based run-off is considered in Section 7.3.11.

Management of coastal development is mainly through the application of Queensland Government legislation and policy. Since 2009, there have been several significant changes to the planning and development framework under the Sustainable Planning Act.

The 2013 State Planning Policy[18] defines the Queensland Government's policies about matters of state interest in land use planning and development. It recognises biodiversity, coastal environment, cultural heritage, water quality and natural hazards as some of the state interests and sets out outcomes and requirements in relation to each. Guidelines support the policy by including model assessment codes for coastal development and further explanation on how the policy outcomes can be achieved at regional and local level. The new policy framework has not been in effect long enough to assess its effectiveness in supporting the management of coastal development to protect the Region.

It is too early to judge the effectiveness of changes to coastal development policy.

While some coastal areas are protected through tenure such as protected areas, this does not provide confidence that the Region's values are being protected. It is not clear how risks such as the loss of coastal wetlands and modification of floodplains are addressed or mitigated under the new state planning policy.

The provisions of the Environment Protection and Biodiversity Conservation Act and, in some cases, the Great Barrier Reef Marine Park Act, address the environmental impacts of some coastal works.

As a result of the Outlook Report 2009, the Great Barrier Reef Marine Park Authority developed a comprehensive report, *Informing the Outlook for the Great Barrier Reef Coastal Ecosystems*[19]. It provides an effective context for management, describing the functioning of the Reef's coastal ecosystems, as well as their threats, pressures, risks and trends.

Vulnerability assessments for coastal ecosystems have been undertaken. There is a reasonable understanding of the direct and indirect impacts associated with the development of coastal ecosystems, though there has been little quantification of these impacts. Consequential and cumulative impacts require better understanding and monitoring.

Understanding of connectivity between the Region and its adjacent coast has improved.

Targets and performance measures for coastal ecosystems are included in the Great Barrier Reef Marine Park Authority's biodiversity conservation strategy[13], but they lack outcome targets, and cannot address coastal development due to jurisdictional responsibilities. The joint Australian and Queensland government *Reef Water Quality Protection Plan*[20] (Reef Plan), which focuses on agricultural land-based run-off, contains performance measures relating to coastal ecosystems.

Stakeholder engagement on coastal ecosystem management is increasing, including through Reef Plan activities, the Australian Government Reef Programme and the Reef Guardian partnerships of the Great Barrier Reef Marine Park Authority.

There is a lack of consistent goals and objectives to guide coastal development across all the agencies and sectors.

Improved land management practices are reducing pollutant loads into the Region

7.3.11 Land-based run-off

The Queensland Government has overall legislative responsibility for the management of land-based run-off in the Great Barrier Reef catchment. Healthy Water Management Plans are a legislative tool that implements water quality actions. There are additional major programs, coordinated through Reef Plan, aimed at improving the quality of land-based run-off through improved land management practices, as well as supporting research and monitoring programs. These on-ground activities, supported by education, community awareness, stewardship and best practice activities are managed through partnerships between the Queensland Government, the Great Barrier Reef Marine Park Authority, the Australian Government Department of the Environment, regional natural resource management bodies, landholders and industry groups.

Revision and updating of Reef Plan in 2009 and 2013 and complementary Australian and Queensland government initiatives have addressed many of the shortfalls identified in the Outlook Report 2009, such as slow progress in achieving outcomes and a lack of monitoring. Regular reviews of Reef Plan have provided better focus and direction for managers, including clear targets for water quality and land management improvement. The plan is focused on outcomes and takes into account new policy documents and regulatory frameworks. Measurable targets, improved accountability, and coordinated monitoring, evaluation and reporting underpin it.

Programs addressing land-based run-off have better focus, clearer targets, coordinated monitoring and improved outputs.

Development by the Great Barrier Reef Marine Park Authority of water quality guidelines and a *Coastal Ecosystems Assessment Framework* set limits for water entering the Marine Park and provide a framework for assessing ecosystem services within basins. The Reef Guardian program has also been expanded to include farmers, graziers and fishers.

The values relevant to water quality are well understood by managers. Key variables, such as sediment, nutrient and pesticide loads, are comprehensively measured. While many of the direct and indirect impacts are well known, knowledge is not as comprehensive concerning consequential and cumulative impacts, although it has improved through the *2013 Scientific Consensus Statement*[21].

In terms of assessing performance, a Reef Plan monitoring, evaluation and reporting strategy has been developed and annual Reef Plan report cards have been published. In addition, all Australian Government grants require regular reporting and evaluation.

While the Australian and Queensland governments have allocated significant resources to understanding the biophysical aspects of water quality, information is still limited with respect to the socioeconomic impact of loss of ecosystem services from poor water quality. The Social and Economic Long-term Monitoring Program managed by CSIRO and commenced in 2011 should improve managers' understanding of people's values and perceptions.

Poor outcomes in the Region for land-based run-off are largely due to the issue's scale and lags within the system.

The impacts of land-based run-off are considered one of the greatest threats to the Great Barrier Reef. Average pollutant loads in land-based run-off are estimated to have declined in the past two years. This has been attributed to improved land management practices by landholders. The work being undertaken by the Australian and Queensland governments, in addition to regional natural resource management bodies, industry and stakeholders implementing Reef Plan, water quality improvement plans and other programs is to be commended. The monitoring programs and improved knowledge about the impacts of land-based run-off are also world class. The assessments of processes and outputs for this management topic have improved considerably since 2009. The lagging response in desired outcomes is largely a result of the scale of the problem and the time needed to effect change in the system.

Managing to protect the Region's values

7.3.12 Biodiversity values

Protection of the biodiversity of the Great Barrier Reef is the primary objective of much of the management action undertaken in the Region and its catchment. A number of Australian and Queensland government agencies have relevant statutory responsibilities, including the Great Barrier Reef Marine Park Authority, the Queensland Parks and Wildlife Service, the Queensland Department of Environment and Heritage Protection, the Australian Government Department of the Environment and the Australian Quarantine Inspection Service. A potentially complex and confusing management regime has been simplified through intergovernmental coordination, for example, complementary zoning plans and joint marine parks permits.

Threat abatement plans, recovery plans and specific on-the-water actions are in place to address individual biodiversity issues. With regard to threatened species, these have had some effect in stabilising populations, but there are few examples of population recovery. More generally, assessments show more species are continuing to decline than have stabilised or are increasing, although status is uncertain for many groups.

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 major threats to biodiversity, such as climate change, coastal development and land-based run-off, are generally outside the scope of this plan and other regional-scale biodiversity protection measures. There is a need to review cross-jurisdictional mechanisms in areas such as planning, coastal development and fisheries management to ensure they are being effectively applied to protecting and restoring ecosystem health.

Partnerships to address starfish outbreaks

In the period 2012 to 2015, the Australian Government has committed to investing more than $7 million in a targeted program for crown-of-thorns starfish removal. The program is managed by the Great Barrier Reef Marine Park Authority in partnership with the Association of Marine Park Tourism Operators. Following the identification of starfish hotspots through the joint Field Management Program, the Association of Marine Park Tourism Operators is responsible for starfish removal. Priority is given to sites of high value to Reef tourism and, where possible, conducting broader-scale control. The program also assists researchers, trains tourism staff in culling methods and collects data on reef health. Between August 2012 and December 2013, 8333 two-minute manta tows were completed along 1415 kilometres of reef, 2258 Reef Health and Impact Surveys were undertaken and over 190,000 crown-of-thorns starfish were culled (Figure 7.3).

In parallel, the Queensland Government has invested $1 million to control crown-of-thorns starfish through the Skilling Queensland program. Work placement participants assist in small-scale control of crown-of-thorns starfish on selected coral reefs.

Diver using a one-shot injection gun to cull crown-of-thorns starfish

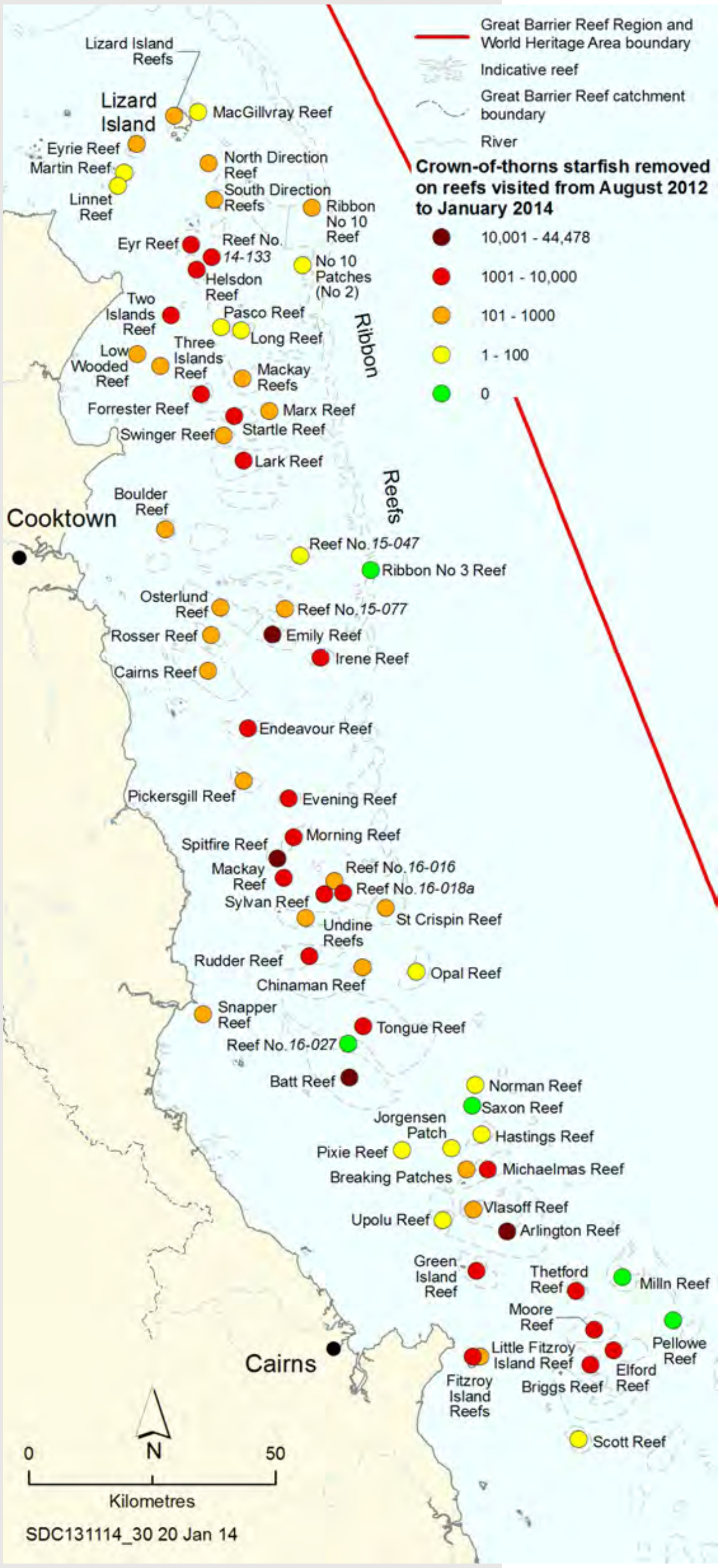


Figure 7.3 Removal of crown-of-thorns starfish, offshore Cairns, August 2012 to January 2014

Reefs where high numbers of starfish have been reported are targeted for repeat visits in the program. Effort is focused on one or more sites at each reef. The map shows the number of starfish removed from each reef. Source: Data provided by the Association of Marine Park Tourism Operators 2014

Planning for biodiversity management has been significantly improved since the 2009 assessment through preparation of the *Great Barrier Reef Biodiversity Conservation Strategy 2013*[13], although targets in the plan tend to be focused on process and output rather than outcomes.

The processes of developing outlook reports and undertaking the strategic assessment for the Great Barrier Reef Region[12] have focused attention on the Region's biodiversity values and threats to those values. The declines in coral cover are cause for considerable concern. To date, there is no explicit overarching strategy and action plan to address this decline. The extensive degradation in central and southern inshore areas highlights the importance of considering cumulative and consequential impacts. These are less well understood by managers, but work[22,23] has begun to address this deficiency.

There is an improved focus on biodiversity outcomes, including an overarching strategy.

The information base for biodiversity management continues to improve through both scientific research and the compilation of information by managing agencies (for example the Great Barrier Reef Marine Park Authority's vulnerability assessments and strategic assessment). Gaps in knowledge are well recognised. Considerable financial resources are allocated to improving understanding of biodiversity and the factors affecting it, including through institutions such as the Australian Institute of Marine Science, universities and the Great Barrier Reef Foundation. Relevant Traditional Owner knowledge is often not available or accessible to managers.

Resources within the Great Barrier Reef Marine Park Authority have been re-focused into relevant areas enabling development of products such as the biodiversity conservation strategy and vulnerability assessments. However, resources for implementation of actions from this work are yet to be identified. The capacity of the Field Management Program to address biodiversity management issues in marine and island environments is assessed as very limited and decreasing.

Key stakeholders in biodiversity protection have been identified and are generally well known to managers especially through the advisory committees of the Great Barrier Reef Marine Park Authority and other consultative mechanisms.

Protection of biodiversity is a primary management objective © Chris Jones

7.3.13 Heritage values

In this assessment, the topic of 'heritage' encompasses Indigenous heritage values, historic heritage values, social and scientific heritage values (including aesthetic heritage values), world heritage and national heritage values, and Commonwealth heritage values as set out in Chapter 4. The effectiveness of measures to protect and manage natural heritage values is considered in the assessment of management to protect biodiversity values (Section 7.3.12).

The Great Barrier Reef Marine Park Authority has statutory responsibilities in relation to the protection of all heritage values in the Great Barrier Reef Marine Park, including consideration of potential impacts during the permit assessment process. The Australian Government Department of the Environment is the lead agency in relation to world, national and Commonwealth heritage matters overall. Historic shipwrecks are protected through specific legislation and entry controls.

Development of the draft *Great Barrier Reef Region Strategic Assessment Report*[12] considerably strengthened understanding of the scope of heritage values associated with the Region.

The *Great Barrier Reef Marine Park Heritage Strategy*[24], endorsed in 2005, identifies actions but does not indicate timing or priorities. The strategy is not fully implemented and has not been updated to effectively address major pressures and drivers. This is the substantive reason why the planning grading has declined since the Outlook Report 2009.

There is generally a reasonable understanding by managers of the Region's historic heritage values and an audit of historic heritage on Commonwealth islands has improved specific knowledge. Little is known about the condition and trend of shipwrecks, World War II sites and heritage places. Consequential and cumulative impacts are not well understood.

Statutory heritage management plans for two lightstations are registered and development of another is underway. Policy documents relevant to historic heritage have not been updated or fully implemented. Resourcing of the management of historic heritage is generally poor. The frameworks for engagement with stakeholders, industry and the community are good, but implementation is limited due to staff resources.

The Region's heritage values are better defined and there is an increasing management focus.

Knowledge of Indigenous heritage values is improving; however, information on direct, indirect and cumulative impacts is not widely available and therefore not well understood or considered by managers.

The Australian Government Reef Programme Land and Sea Country Indigenous Partnerships Programme articulates a set of objectives and targets to ensure *'continued use, support and reinvigoration of traditional ecological knowledge to underpin biodiversity conservation'*. This program has met all its targets and has been extended to 2018. The Great Barrier Reef Marine Park Authority's strategic plan includes specific objectives concerning working with Aboriginal and Torres Strait Islanders including in matters relevant to Indigenous heritage values.

While progress has been made in engaging with key Traditional Owner groups, further work is needed to develop a mutually agreed and culturally appropriate process for joint planning. An Indigenous cultural heritage strategy would enable a shared vision to be developed with Traditional Owner groups with actions and timeframes for implementation.

The protection, presentation and transmission of the outstanding universal value of the Great Barrier Reef World Heritage Area are integrated into most activities to protect and manage the Region. The attributes that make up the property's outstanding universal value are articulated, and risks, threats and management progress are closely monitored and annually reported through State Party reports.

7.3.14 Community benefits of the environment

In this assessment, the topic of 'community benefits of the environment' encompasses cultural, social and economic benefits such as employment, income, understanding, appreciation, enjoyment, personal connection, health benefits and access to Reef resources.

The Great Barrier Reef Marine Park Authority, together with other Australian and Queensland government agencies, works to adopt an integrated approach to the management of the social, economic and environmental aspects of the Region.

Social values are considered in permit assessments, but this is limited by a lack of detailed understanding and knowledge. The consequential and cumulative impacts on community benefits as a result of activities within and adjacent to the Region are not well documented nor assessed thoroughly. Community benefit issues are often considered under programs and policies developed for other purposes.

Understanding of community benefits is improving; their consideration lacks a policy framework.

Development of the draft *Great Barrier Reef Region Strategic Assessment Report*[12] considerably strengthened understanding of community benefits derived from the Region, including their current condition and threats to them. Early results from the Social and Economic Long-term Monitoring Program have improved understanding. The importance of the Reef in Indigenous economies is not well understood and not incorporated fully into management.

Many of the factors influencing community benefits, such as population growth, economic growth and climate change, are global drivers and are difficult for a single management system to encompass. However, the *Recreation Management Strategy for the Great Barrier Reef Marine Park*[9] made some progress towards recognising enjoyment and personal attachment to the Reef.

Objectives for community benefits are reflected in Great Barrier Reef Marine Park Authority activities such as the Reef Guardian program, Reef HQ Aquarium, and the recreation management strategy. The joint Field Management Program has a strong commitment to ensuring public access to the Reef and islands.

Stakeholder engagement, for example through the advisory committees of the Great Barrier Reef Marine Park Authority and during development of the Great Barrier Reef Region strategic assessment, contributes to managers' understanding of community values and issues of concern. Volunteer programs, such as components of the Marine Monitoring and Eye on the Reef programs, provide avenues for community involvement in protecting the Great Barrier Reef.

There are no guidelines or policies for decision makers in relation to managing for community benefits. An overarching strategy would clarify objectives, roles and responsibilities in relation to community benefits. It would also provide an improved framework to assess management effectiveness with greater accuracy.

7.4 Assessment of management approaches

The purpose of this section is to assess the three broad management approaches as described in Section 7.1.3 — environmental regulation, engagement, and knowledge, integration and innovation — across all management topics. The findings are based on the assessments carried out for each of the management topics.

7.4.1 Environmental regulation

Statutory instruments employed in protection and management of the Region's ecosystem and heritage values are generally contemporary and appropriate. Commonwealth legislation has been reviewed to keep pace with emerging issues, and two key legislative instruments, the Environment Protection and Biodiversity Conservation Act and the Great Barrier Reef Marine Park Act, have been aligned. Relevant Queensland legislation is not necessarily consistent with that of the Commonwealth, often due to differences in objectives. Joint marine parks permits have been provided for some time, and governments are committed to a 'one-stop shop' approach with respect to approvals.

Environmental regulation is generally contemporary and appropriate; some needs updating and aligning.

Revised coastal development arrangements through implementation of the new State Planning Policy are yet to be determined, as are arrangements for the devolution of environmental impact assessment processes.

Zoning plans have been very effective for managing activities such as fishing, resulting in improved biodiversity protection outcomes. However, other than setting out the requirement for a permit, they do not address activities such as tourism which are principally managed through plans of management and permits. While plans of management are a useful tool, they require updating, and there is a need for them to be developed in areas experiencing increasing impacts from use.

Compliance systems are very sophisticated, and are very effective for activities of highest risk to the Region's values, such as illegal fishing and poaching. Due to funding issues, the joint Field Management Program must prioritise compliance activities, based on a detailed risk analysis, and is not able to comprehensively enforce legislation.

A number of policies and strategies have been considerably improved or developed since the 2009 assessment, for example in relation to climate change, recreation, biodiversity and land-based run-off. Some of these would benefit from targets focused on outcomes, with clear objectives, actions and milestones. An example of a highly effective strategy is the *Reef Water Quality Protection Plan*[20] — a joint Australian and Queensland government program. Some policies require significant review, and plans for regular review and evaluation are generally lacking. There is a lack of policy guidance in areas such as Indigenous heritage values and community benefits.

7.4.2 Engagement

The intergovernmental agreement between the Australian and Queensland governments articulating the joint management arrangements for the Great Barrier Reef is world-leading. It has been in place since 1979 and was updated in 2009 to ensure that contemporary issues and challenges were suitably addressed. The joint Field Management Program set up through the agreement works well and is also a model for the rest of world. This arrangement requires the two governments to jointly develop priorities for activities and allocate funding. The greatest concern with the partnership is a lack of resourcing to enable staff to undertake required management across all activities in the world heritage area. Further positive collaboration between agencies both within and across levels of government is through programs such as implementing Reef Plan.

Research collaboration between government agencies and research providers is positive and proactive.

There has been very positive progress in partnerships with Traditional Owners, especially through the Australian Government Reef Programme Land and Sea Country Indigenous Partnership Programme. The Great Barrier Reef Marine Park Authority is engaged with over 80 per cent of Traditional Owners that have connections to sea country in the Region and continues to work closely with them in relation to its management. Indigenous employment, especially through the Field Management Program and the Indigenous community compliance liaison officers, has been strongly supported. There continues to be poor transfer of traditional knowledge from Traditional Owners to managing agencies, and as a result it is not being taken into account in many management decisions or actions.

The development of partnerships and stewardship arrangements is one of the strongest aspects of management of the Region and knowledge of stakeholders is the highest ranked indicator overall. The Reef Guardian program of the Great Barrier Reef Marine Park Authority is an acknowledged example of a successful stewardship approach. More broadly, the success of Reef Plan depends on forming partnerships with regional natural resource management bodies and, through them, with land managers.

Partnerships and stewardship programs are also key elements of management with the tourism and fishing sectors, for example in planning for climate change, adoption of best practices and reef health monitoring.

The Great Barrier Reef Marine Park Authority's engagement activities are underpinned by long-standing consultation arrangements with key sectors and regions, including through Local Marine Advisory Committees and Reef Advisory Committees.

Partnerships and stewardship arrangements are one of the strongest aspects of management.

Lama Lama Traditional Owners taking part in a joint management patrol

7.4.3 Knowledge, innovation and integration

Research and monitoring: The Outlook Report process and the comprehensive strategic assessment for the Great Barrier Reef World Heritage Area have accumulated and consolidated knowledge relevant to the Region and made it more widely available. In addition these processes have identified key knowledge gaps, for example through the scientific information needs process following the Outlook Report 2009[10], and have stimulated programs and projects to fill them.

Monitoring relevant to management has expanded, both in scope and scale. The long-term monitoring program managed by the Australian Institute of Marine Science continues to provide critical data on the Region's ecosystem and demonstrates the value of maintaining consistent monitoring over an extended time period. The recently developed social and economic long-term monitoring program is beginning to address deficiencies in understanding of socioeconomic aspects.

The development of an integrated monitoring framework and program is a positive initiative that will help address deficiencies in monitoring, especially in relation to cumulative impacts and overall ecosystem health. The Eye on the Reef program consolidates monitoring and reporting by managers, Reef users and the community and already has a large set of data across a wide geographic area.

An integrated framework will help address deficiencies in monitoring.

Reporting and evaluation: The five-yearly Great Barrier Reef Outlook Report process provides the most comprehensive, regular basis for evaluation and reporting on management of the Great Barrier Reef. Its model and process, including the independent assessment of management effectiveness, has been widely acknowledged as ground-breaking. It has been adapted for Australian State of Environment reporting and elsewhere, including internationally. The five-yearly reports can be supported by in-depth assessments of particular issues, for example the 2012 report on the outlook for coastal ecosystems[19].

Up to the end of 2013, implementation of Reef Plan had been evaluated in three annual report cards. The process and content of Reef Plan reporting in the latest report card released in 2013 is significantly improved by contributions from all partners in the program and enhanced depth and quality of monitoring information. All Australian Government-funded projects require structured monitoring and evaluation.

The draft reports of the comprehensive strategic assessment of the Great Barrier Reef World Heritage Area present a one-off, comprehensive evaluation of marine and coastal management in the Region.

Keeping an Eye on the Reef

Overall understanding of the Reef ecosystem, knowledge available for management and engagement with a variety of Reef stakeholders have all been improved through development of an integrated Eye on the Reef program. Managed by the Great Barrier Reef Marine Park Authority in collaboration with the Queensland Parks and Wildlife Service, the program is a network of monitoring programs that engages and benefits Australian and Queensland government managing agencies, researchers, fishers, tourism operators and community groups.

The program includes structured Reef Health and Impact Surveys, the Tourism Weekly Monitoring program, the Rapid Monitoring survey program and the Sightings Network. In combination, these programs provide everything from information on sightings and unusual events to an early warning system and on-the-spot impact assessments used to promptly inform responses to incidents such as coral bleaching and cyclones. Within a fortnight of severe tropical cyclone Yasi in 2011, 882 Reef Health and Impact Surveys had been completed, providing a comprehensive assessment of reef damage at over 76 reefs.[16] The monitoring surveys undertaken through the Eye on the Reef program provide detailed information about a number of sites spread across the Region (Figure 7.4).

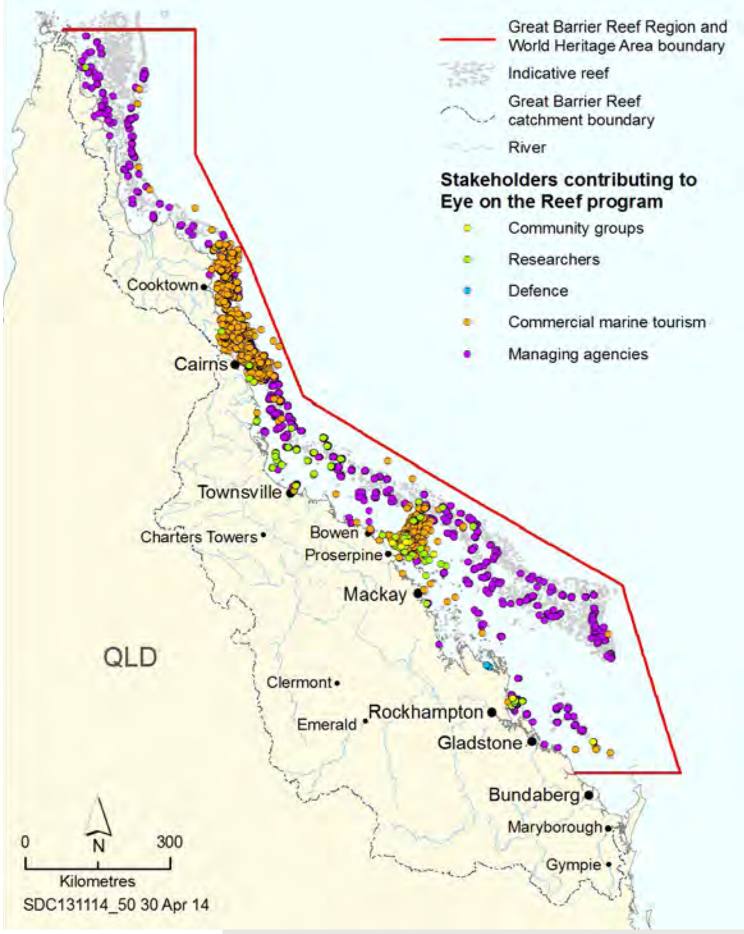


Figure 7.4 Eye on the Reef reporting locations and key contributors 2008–2013
A range of different people and groups contribute data to the Eye on the Reef program. The map shows Eye on the Reef contributions are widely spread across the Region. Source: Great Barrier Reef Marine Park Authority 2013[25]

Contributions to the Eye on the Reef program are improving knowledge available for management

7.5 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. Section 116A(2)(d) of the *Great Barrier Reef Marine Park Regulations 1983* requires '… *an assessment of the existing measures to protect and manage the heritage values*…' of the Great Barrier Reef Region.

The assessment was undertaken by four independent 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.

7.5.1 Understanding of context

Outlook Report 2009: Assessment summary
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).

2009 Grade	Current summary	Assessment grade and trend			
		Very good	Good	Poor	Very poor
🟦	**Understanding of context:** Context is the strongest management effectiveness element and trends are either stable or improving. Understanding of values, direct and indirect threats and stakeholders is generally strong. Understanding of cumulative and consequential impacts as well as condition and trend is improving and has been effectively documented through the Outlook Report and strategic assessment processes. In particular, tourism, defence activities, recreation, research activities and land-based run-off are well understood. This reflects a solid information and research base and a very mature understanding of the key values of the Region.	🟦 ↑			

Grading statements				Trend since 2009
🟦 **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.	↑ Improved ↔ Stable ↓ Deteriorated — No consistent trend

7.5.2 Planning

Outlook Report 2009: Assessment summary
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.

2009 Grade	Current summary	Assessment grade and trend			
		Very good	Good	Poor	Very poor
🩵	**Planning:** Significant efforts have been made in planning for a number of topics such as biodiversity protection and recreation. Planning effectiveness has declined for climate change measures specific to the Region, principally as a result of changing policy and a lack of clarity about future directions. It has also declined for commercial marine tourism and research activities, largely because plans and policies have not been completed or updated. For coastal development, the fractured nature of the planning regime is problematic and recent changes have raised concerns. Planning effectiveness has improved for the management of land-based run-off and traditional use where the investment of resources is paying dividends. Lack of consistency across jurisdictions is the weakest aspect of planning.		🩵 ↔		

Grading statements				Trend since 2009
🟦 **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.	↑ Improved ↔ Stable ↓ Deteriorated — No consistent trend

7.5.3 Financial, staffing and information inputs

Outlook Report 2009: Assessment summary
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 socioeconomic and access to relevant Traditional Owner knowledge is a problem for most issues and one of the worst performing criteria across the whole assessment.

2009 Grade	Current summary	Assessment grade and trend			
		Very good	Good	Poor	Very poor
🟩	**Financial, staffing and information inputs:** Adequacy of inputs is variable across management topics, being least effective for community benefits, coastal development, and non-Indigenous heritage management. Poor understanding of heritage values is a problem for most issues and is among the worst performing criteria across the whole assessment. Availability of socioeconomic knowledge has improved. Substantial resources have been devoted to the topics of land-based run-off and traditional use. Secure resourcing is a significant ongoing problem for many management topics. In many cases the lack of adequate resources to advance planning and management is constraining the effectiveness of other aspects of management.			🟩 ↔	

Grading statements				Trend since 2009
🟦 **Very good** Financial and staffing resources are largely adequate to meet management needs. Biophysical, socioeconomic and Traditional Owner knowledge is available to inform management decision making.	🟦 **Good** Financial and staffing resources are mostly adequate to meet management needs. Biophysical, socioeconomic 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, socioeconomic 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, socioeconomic and Traditional Owner knowledge to support decision making is frequently deficient in some areas.	↑ Improved ↔ Stable ↓ Deteriorated ▬ No consistent trend

7.5.4 Management systems and processes

Outlook Report 2009: Assessment summary
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 socioeconomic 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.

2009 Grade	Current summary	Assessment grade and trend			
		Very good	Good	Poor	Very poor
🟦	**Management systems and processes:** Management processes are particularly strong for defence activities, shipping and management of land-based run-off. They are weakest for coastal development, community benefits and Indigenous heritage values. Addressing consequential and cumulative impacts, application of socioeconomic and Indigenous knowledge, and setting of targets to benchmark performance are problematic for most issues. Consideration of cumulative and consequential impacts has improved substantially. Stakeholder engagement and application of biophysical information are the strongest aspects of management across all issues.		🟦 ↓		

Grading statements				Trend since 2009
🟦 **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.	↑ Improved ↔ Stable ↓ Deteriorated ▬ No consistent trend

7.5.5 Delivery of outputs

Outlook Report 2009: Assessment summary
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.

2009 Grade	Current summary	Assessment grade and trend			
		Very good	Good	Poor	Very poor
🟦	**Delivery of outputs:** Delivery of desired outputs was rated as effective or very effective for all topics except coastal development. It is strongest for commercial marine tourism, defence activities, research activities and land-based run-off, where there has been a noticeable improvement. The knowledge base of managing agencies and the community has consistently improved. While the majority of management programs are progressing satisfactorily, timeframes frequently slip and it is not yet clear that the programs are achieving all their desired objectives.		↔		

Grading statements				Trend since 2009
🟦 **Very good** Management programs are mostly progressing in accordance with planned programs and are achieving their desired objectives. Managing 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. Managing 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.	↑ Improved ↔ Stable ↓ Deteriorated ▬ No consistent trend

7.5.6 Achievement of outcomes

Outlook Report 2009: Assessment summary
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.

2009 Grade	Current summary	Assessment grade and trend			
		Very good	Good	Poor	Very poor
🟩	**Achievement of outcomes:** Achievement of desired outcomes is highly variable across the management topics. Objectives in relation to community understanding of issues and development of effective partnerships are being achieved. Performance in outcomes is especially strong for research activities, shipping and defence activities. Overall, the weakest performance was for climate change, then coastal development, land-based run-off and fishing. For land-based run-off, the continued poor outcomes for the Region are largely due to scale of the problem and lags within the natural system.			↓	

Grading statements				Trend since 2009
🟦 **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.	↑ Improved ↔ Stable ↓ Deteriorated ▬ No consistent trend

7.5.7 Overall summary of existing protection and management

The effectiveness of existing measures to protect and manage the Region's ecosystem and its heritage values was independently assessed for 14 broad management topics.[2] The activities of all relevant Australian and Queensland government agencies and other contributing partners were considered. The outcomes are summarised in Figure 7.5.

Managing agencies are striving to manage effectively in all areas. Since the independent assessment for the Outlook Report 2009, there have been considerable improvements in parts of the management cycle for a number of management topics, in part as a result of the outcomes of that assessment and the overall findings of the report. For example, outcomes for the traditional use of marine resources have improved following better planning, inputs and processes, and program outputs for land-based run-off have improved following improvements in planning (for example revisions to Reef Plan), inputs and processes. Undertaking the comprehensive strategic assessment of the Great Barrier Reef World Heritage Area has further consolidated understanding about the Region, its values and threats, and focused management attention.

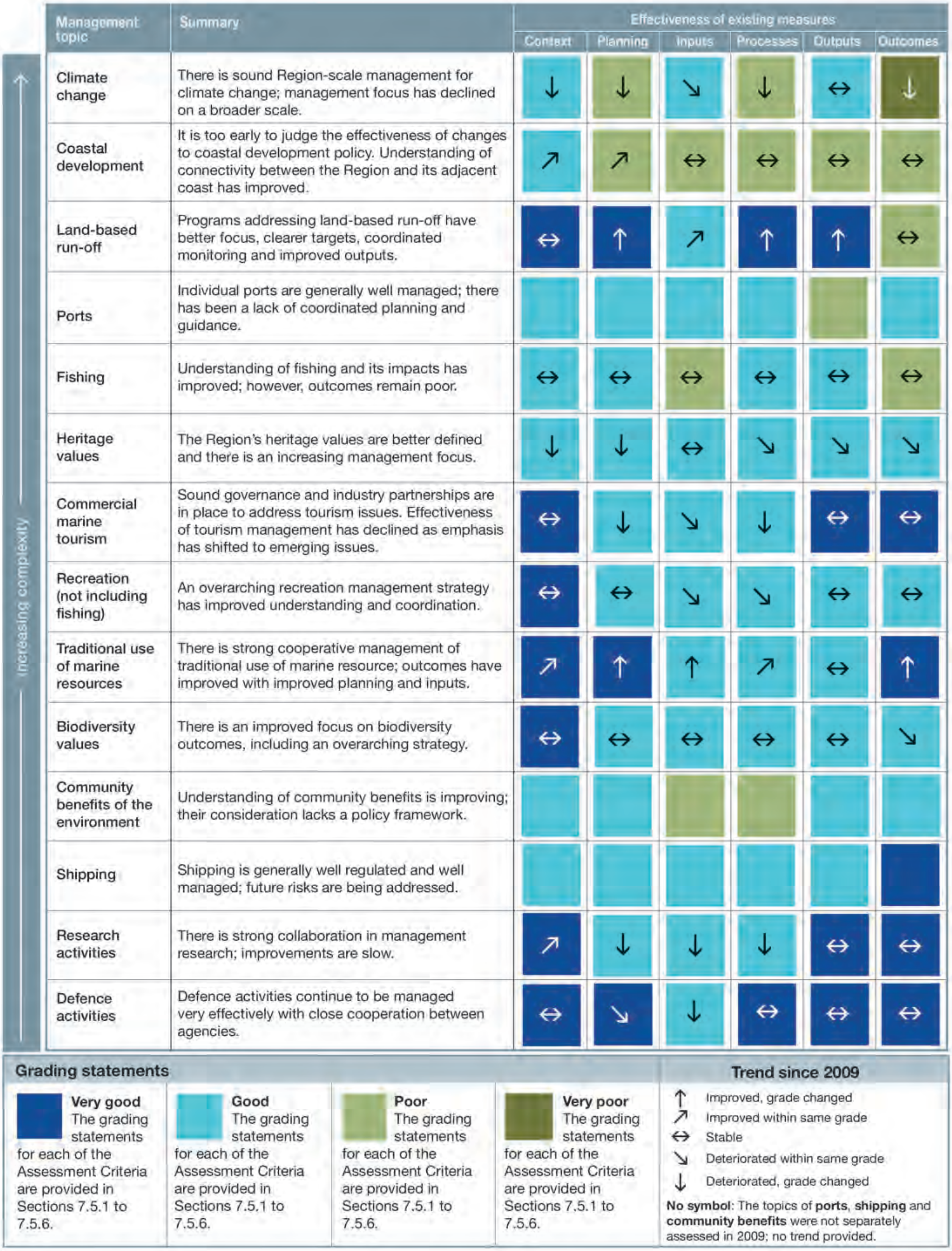
The difficulties in achieving positive outcomes on the ground, given the complexity of many issues, the spatial and temporal scales of the threats to the Region's values and the diminishing resource base to implement actions, are recognised. Progress in reducing the threats is slow and is reflected in the continuing poor outcomes for some management topics. Desired outcomes are difficult to achieve for some of the most significant (and complex) management issues threatening the Region.

Not surprisingly, performance across the six elements tends to be better for the less complex management topics (Figure 7.5). Two issues do not follow this general pattern. Land-based run-off is one of the more complex topics and yet is generally effectively managed (although outcomes remain only partially effective). This result demonstrates the impact that significant commitment of resources, extensive planning responses, and extensive research to inform management can have on the management of an issue. The lagging response in desired outcomes for the Region is largely a result of the scale of the problem and the time needed to effect change in the system. In contrast, community benefits of the environment is a less complex topic that shows only partially effective management in inputs and processes. This is likely a reflection of its relatively recent recognition as an area of management.

While commercial marine tourism has previously received significant management attention and is effectively managed overall, there is a trend that efforts within management agencies are being redirected to tackle higher risks, resulting in less effective tourism management (for example, the overdue need to review the plans of management).

In the case of climate change and coastal development, there are particular management challenges in consistency across jurisdictions which affect the effectiveness of planning. For fishing, there are particular challenges in the areas of monitoring and compliance, especially as they relate to addressing potential cumulative impacts. For heritage values other than natural heritage values, the management challenges are particularly in areas of understanding the values and better incorporating their consideration in decision making, although substantial progress has been made.

Volunteers collected 335 kilograms of rubbish from Neck Bay in the Whitsundays during this Eco Barge Clean Seas marine debris clean up



Management topic	Summary	Effectiveness of existing measures					
		Context	Planning	Inputs	Processes	Outputs	Outcomes
Climate change	There is sound Region-scale management for climate change; management focus has declined on a broader scale.	🔷 ↓	🟩 ↓	🔷 ↘	🟩 ↓	🔷 ↔	🟫 ↓
Coastal development	It is too early to judge the effectiveness of changes to coastal development policy. Understanding of connectivity between the Region and its adjacent coast has improved.	🔷 ↗	🟩 ↗	🟩 ↔	🟩 ↔	🟩 ↔	🟩 ↔
Land-based run-off	Programs addressing land-based run-off have better focus, clearer targets, coordinated monitoring and improved outputs.	🟦 ↔	🟦 ↑	🔷 ↗	🟦 ↑	🟦 ↑	🟩 ↔
Ports	Individual ports are generally well managed; there has been a lack of coordinated planning and guidance.	🔷	🔷	🔷	🔷	🟩	🔷
Fishing	Understanding of fishing and its impacts has improved; however, outcomes remain poor.	🔷 ↔	🔷 ↔	🟩 ↔	🔷 ↔	🔷 ↔	🟩 ↔
Heritage values	The Region's heritage values are better defined and there is an increasing management focus.	🔷 ↓	🔷 ↓	🔷 ↔	🔷 ↘	🔷 ↘	🔷 ↘
Commercial marine tourism	Sound governance and industry partnerships are in place to address tourism issues. Effectiveness of tourism management has declined as emphasis has shifted to emerging issues.	🟦 ↔	🔷 ↓	🔷 ↘	🔷 ↓	🟦 ↔	🟦 ↔
Recreation (not including fishing)	An overarching recreation management strategy has improved understanding and coordination.	🟦 ↔	🔷 ↔	🔷 ↘	🔷 ↘	🔷 ↔	🔷 ↔
Traditional use of marine resources	There is strong cooperative management of traditional use of marine resource; outcomes have improved with improved planning and inputs.	🟦 ↗	🟦 ↑	🔷 ↑	🔷 ↗	🔷 ↔	🟦 ↑
Biodiversity values	There is an improved focus on biodiversity outcomes, including an overarching strategy.	🟦 ↔	🔷 ↔	🔷 ↔	🔷 ↔	🔷 ↔	🔷 ↘
Community benefits of the environment	Understanding of community benefits is improving; their consideration lacks a policy framework.	🔷	🔷	🟩	🟩	🔷	🔷
Shipping	Shipping is generally well regulated and well managed; future risks are being addressed.	🔷	🔷	🔷	🔷	🔷	🟦
Research activities	There is strong collaboration in management research; improvements are slow.	🟦 ↗	🔷 ↓	🔷 ↓	🔷 ↓	🟦 ↔	🟦 ↔
Defence activities	Defence activities continue to be managed very effectively with close cooperation between agencies.	🟦 ↔	🟦 ↘	🔷 ↓	🟦 ↔	🟦 ↔	🟦 ↔

Grading statements

- 🟦 **Very good** The grading statements for each of the Assessment Criteria are provided in Sections 7.5.1 to 7.5.6.
- 🔷 **Good** The grading statements for each of the Assessment Criteria are provided in Sections 7.5.1 to 7.5.6.
- 🟩 **Poor** The grading statements for each of the Assessment Criteria are provided in Sections 7.5.1 to 7.5.6.
- 🟫 **Very poor** The grading statements for each of the Assessment Criteria are provided in Sections 7.5.1 to 7.5.6.

Trend since 2009

- ↑ Improved, grade changed
- ↗ Improved within same grade
- ↔ Stable
- ↘ Deteriorated within same grade
- ↓ Deteriorated, grade changed

No symbol: The topics of **ports**, **shipping** and **community benefits** were not separately assessed in 2009; no trend provided.

Figure 7.5 Overall assessment of the effectiveness of existing measures to protect and manage the Region's values

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. Trend is not presented where topics were not assessed in 2009: ports and shipping were assessed jointly in 2009 but treated separately here, community benefits were not assessed in 2009. The degree of complexity is based on the analysis provided in Table 7.2.

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Resilience

CHAPTER 8

'an assessment of the current resilience of the ecosystem...' within the Great Barrier Reef Region,
Section 54(3)(e) of the *Great Barrier Reef Marine Park Act 1975*

'an assessment of the current resilience of the heritage values...' of the Great Barrier Reef Region,
Section 116A(2)(c) of the *Great Barrier Reef Marine Park Regulations 1983*

2014 Summary of assessment

Recovery in the ecosystem	Some disturbed populations and habitats have demonstrated recovery after disturbance (for example lagoon floor, loggerhead turtles, humpback whales). For some species, recovery is not evident (black teatfish, dugongs) and is dependent on the removal of all threats. Increasing frequency and extent of some threats are likely to continue to reduce the resilience of species and habitats in the Region.	↓ Poor, Deteriorated
Improving heritage resilience	The resilience of built heritage values has improved where the values are well recorded and well recognised and there is strong regulatory protection and regular maintenance (for example heritage-listed lighthouses). The resilience of intangible values, such as many Indigenous heritage values, depends on the active involvement of the custodians of those values so that connections and knowledge are kept alive. Such involvement has continued to grow.	🟦 Good, Trend not assessed

Full assessment summary: see Section 8.6

< Photograph © Chris Jones

Resilience

8.1 Background

Resilience refers to the capacity of a system to resist disturbance and undergo change while still retaining essentially the same function, structure, integrity and feedbacks.[1] It is not about a single, static state, but rather the capacity of an ever-changing, dynamic system to return to a healthy state after a disturbance or impact.[2,3,4] It is a concept that is applied to both natural and social systems — from habitats and species, to communities, businesses and social assets. Resilience and vulnerability are related concepts.[5,6,7] Resilience (sensitivity and adaptive capacity) is a way of describing the properties of a system and how it responds to exposure to disturbance. Together with exposure, resilience helps determine a system's overall vulnerability. In the Outlook Report 2009, the resilience of the Great Barrier Reef ecosystem was assessed, including through a series of case studies examining recovery after disturbance. In this report, the assessment is expanded to include the resilience of heritage values, also including some case studies. Each case study contains an introduction, a description of current management arrangements and evidence for recovery.

8.2 Ecosystem resilience

> **Outlook Report 2009:** Overall summary of (ecosystem) resilience
>
> ... 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.
>
> ... 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.

Tropical marine ecosystems such as the Great Barrier Reef, and the coastal ecosystems that support them, are subject to a wide range of natural and human-related threats that may damage their components. These ecosystems are resilient if, given sufficient time, they are able to resist or recover from those threats, and maintain key functions without changing to a different state.

A resilient system can resist pressures and return to a healthy state.

Understanding the capacity of the Great Barrier Reef ecosystem to resist and recover from the broad range of threats and disturbances it is facing is crucial to improving its long-term protection.[7,8,9,10,11] There is no comprehensive information on the ecosystem resilience of the Great Barrier Reef Region (the Region), largely due to the vast extent and complexity of the ecosystem, and because resilience is a complex, dynamic property that is difficult to measure. Therefore, this Reef-wide assessment is necessarily broad. It is based on an overall understanding of resilience; evidence presented in previous chapters on the biodiversity and health of the ecosystem, the impacts facing the Region and the effectiveness of management; and some case studies of recovery.

8.2.1 Understanding ecosystem resilience

The resilience of an ecosystem is determined by a range of variables. A loss of ecosystem resilience cannot be attributed to any single cause, but is almost certainly the consequence of impacts from all the different activities and influencing factors, and their accumulation through time.

Systems are likely to have greater resilience if they have high levels of diversity, key functional species to maintain ecological processes and a level of functional redundancy (where species can perform different ecological roles).[12,13] For example, a coral reef with high coral diversity that is affected by a cyclone may lose the more fragile and faster growing branching corals; however, the slower growing, more resistant coral species may be able to maintain the function of the coral reef system until coral diversity returns. Timescales are also important. At a species level, fast growing species may be more resilient in the long term because of their ability to rapidly recolonise.

Ecosystem resilience relies on diversity, healthy processes, strong connectivity and time for recovery.

Networks of components (for example interconnected habitats) may have greater resilience because their connectivity enhances recovery after disturbances.[14,15] In addition, the resilience of an ecosystem is enhanced when connections with supporting ecosystems are functioning effectively and those supporting systems are in good condition.[16] For the Great Barrier Reef, the health of supporting terrestrial and other coastal habitats and functional connections to those habitats (see Section 3.4.10) play an important role in maintaining resilience.[17] Relevant ecological functions and processes provided by terrestrial habitats include physical processes (such as sediment and water distribution), biogeochemical processes (such as nutrient cycling) and biological processes (such as connectivity and recruitment).

The resilience of an ecosystem is also influenced by the extent and frequency of disturbances (exposure) — noting some ecosystems are naturally adapted to frequent (natural) disturbance events.[18] If disturbances are too frequent and the system has insufficient time to recover between disturbances, the impacts can become compounded and resilience reduced. For example, before the 1980s, coral cover on Jamaican reefs ranged from 40 to 70 per cent and macroalgal cover was typically 10 per cent.[19] The resilience of these reefs was subsequently compromised by several disturbances including two major hurricanes[20,21], outbreaks of coral predators and coral disease[22], the regional loss of a keystone herbivore[23], and a series of coral bleaching events[24]. As a result of compounding pressures, the ecosystem has had little time to recover; coral cover has plummeted to 10 per cent and macroalgae has become dominant.[19,25,26]

Although the resilience of the ecosystem is distinct from its overall condition, they are related — a degraded system may have less capacity to recover if species populations are too depleted to supply enough new recruits (for example, larvae or seeds) or if ecosystem processes are no longer functioning effectively. For example, the replenishment of fish and coral larvae to an area after disturbance requires the processes of recruitment, ocean circulation and connectivity to be in good condition.

Resilience must be supported at both local and broad scales.

Thresholds or tipping points are a critical aspect of resilience. An ecosystem subject to ongoing threats and their chronic and acute effects may reach a tipping point and suddenly change in response to a relatively small increase in impacts. For example, a reef subject to excess nutrients and sediments may retain high coral cover, but have low recruitment of new corals. If a storm reduces the coral cover, the lack of recruitment may mean the reef is not able to recover, and suddenly changes state. These changes in state are often referred to as phase-shifts.[9,27,28,29,30]

Addressing local-scale impacts on tropical marine ecosystems is considered critical to building resilience and maintaining healthy ecosystems.[9] If threats and their effects are manifesting at local or regional scales, they may be masked when ecosystem resilience is considered only at broad scales.[17,31]

Ecosystems with high diversity generally have greater resilience

Managing for resilience is most important in situations where there is uncertainty about risks and appropriate management responses.[32] Mitigating and minimising the multiple impacts that affect an ecosystem will improve its overall resilience. Managing agencies, industries and communities can all play a role. For example, where fishing and tourism operators on the Great Barrier Reef and landholders in the catchment practise strong stewardship, pressures are reduced and Reef health and resilience is supported.[33]

8.3 Case studies of recovery in the ecosystem

Although recovery after disturbance is only one aspect of resilience, it is a critical attribute of a resilient system, is practical to measure and monitor, and gives an indication of overall resilience. The series of case studies below illustrate the extent to which some key components of the ecosystem have recovered after disturbance. They provide evidence of the overall resilience of the Great Barrier Reef ecosystem.

The case studies showcase a range of aspects relevant to resilience:

- the extent to which some key functional habitats have responded after human and natural disturbances — coral reef and lagoon floor habitats
- the extent to which some key ecological processes have responded after human and natural disturbances — black teatfish (particle feeding), urban coast dugong (herbivory) and coral trout (predation)
- the effectiveness of specific management actions implemented to address declines in specific species — loggerhead turtles and humpback whales.

The case studies are the same as those in the Outlook Report 2009 so that trends over time can be analysed and reported.

8.3.1 Coral reef habitats

Coral reefs, and corals specifically, have a natural ability to recover from periodic disturbances such as cyclones, crown-of-thorns starfish outbreaks or coral bleaching. Corals on a resilient and relatively undisturbed reef will gradually re-establish their dominance as well as diversity within a couple of decades of a catastrophic coral mortality event.[34,35] However corals exposed to chronic pressures, such as poor water quality, are likely to have less resilience and hence less ability to recover from these acute disturbances.[36,37]

The potential of a coral reef community to recover from disturbance depends on its condition, resilience and the frequency and intensity of disturbances.[15,28,38,39,40] Key indicators of coral condition (health) include coral cover, rates of coral growth during periods free from disturbance, juvenile abundance and macroalgae cover.[36] With sufficient time between disturbances, recovery of coral cover can be substantial, which is evident from long-term data from reefs that have been free from disturbance following impacts such as bleaching[35] and crown-of-thorns starfish outbreaks.[41]

Over the last decade, parts of the Great Barrier Reef have been exposed to repeated disturbance events, especially in the southern two-thirds of the Region (see Section 3.2.2, Section 3.2.3 and Figure 6.7). Figure 8.1 shows spatial extent of exposure of reef area, between 2001 and 2011, to key disturbances at levels that are likely to result in damage. Along with the disturbances mapped — cyclone-induced waves, crown-of-thorns starfish outbreaks, elevated sea surface temperatures and freshwater inflow — there may be more localised disturbances such as vessel groundings and anchor damage.

Management The range of management measures described in the Outlook Report 2009 that are in place to either eliminate or substantially reduce the magnitude and likelihood of threats affecting coral reef habitats[43] remain, and additional measures have been introduced. The *Great Barrier Reef Biodiversity Conservation Strategy 2013*[44] provides a framework for improving biodiversity conservation in the Region, including for coral reefs.

Environmental regulation measures include:

- establishment of zones or special areas prohibiting certain activities
- permit conditions for specific activities
- reef protection markers and moorings
- general protection of coral species in the Great Barrier Reef Marine Park
- fisheries legislation and associated (conditional) accreditation of the export component of the commercial coral harvest fishery under national sustainability guidelines.

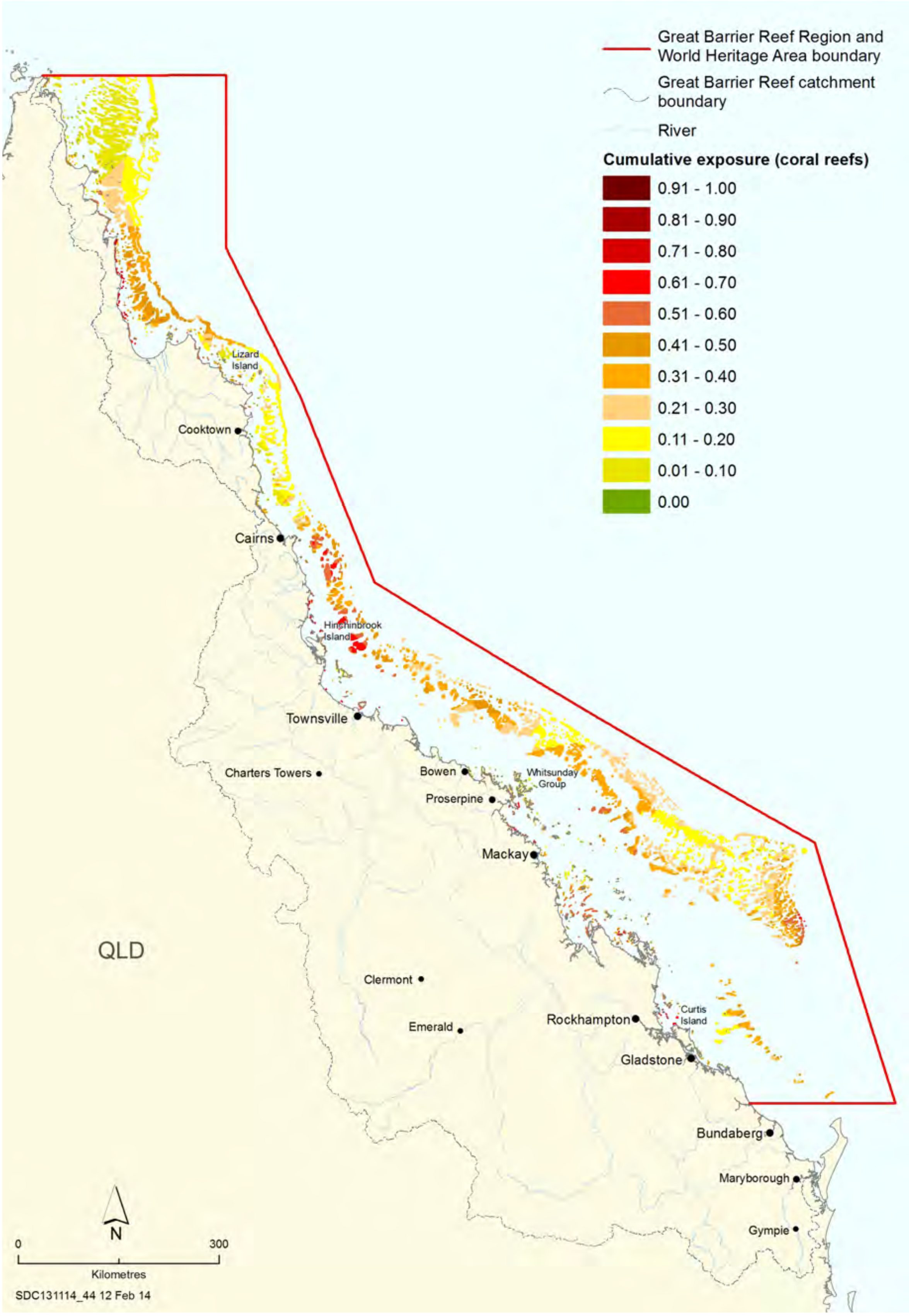


Figure 8.1 Cumulative exposure of coral reefs to key disturbances, 2001–2011
The map presents the modelled cumulative exposure of coral reefs to the following disturbances: cyclone-induced waves, crown-of-thorns starfish outbreaks, elevated sea surface temperatures and freshwater inflow.[42] *The magnitude of the impacts has been normalised between zero and one. The higher the exposure number, the greater the exposure to the disturbances modelled. Exposure to disturbance and coral health are not necessarily directly correlated; the effect of disturbance depends on a reef's capacity to resist and recover.* Source: Johnson *et al.* 2013[42]

Engagement-related measures include:

- Guidelines and codes of conduct, for example best practices for snorkelling, diving and anchoring
- implementation of activities to improve water quality by reducing the run-off of nutrients, sediments and pesticides (including under the *Reef Water Quality Protection Plan 2013* (Reef Plan)[45] and the *Australian Government Reef Programme*)
- implementation of a crown-of-thorns starfish control program
- development of industry-led guidelines for aquarium supply collection practices[46].

A wide range of measures address coral reef protection.

Knowledge, innovation and integration measures include:

- research and monitoring to assess impacts and monitor ecosystem condition[33,47,48,49]
- social and economic long-term monitoring program[50]
- development of new incident response plans for coral disease, bleaching and tropical cyclones[51,52,53]
- significant expansion and integration of the Eye on the Reef program components and data management platform
- assessment and improved understanding of terrestrial ecosystem function and processes important to the long-term health of the Great Barrier Reef[38].

The biodiversity conservation strategy, the starfish control program, the stewardship guidelines, social and economic monitoring, incident response plans, expansion and integration of the Eye on the Reef program and improved understanding of coastal ecosystems have all been introduced since the Outlook Report 2009.

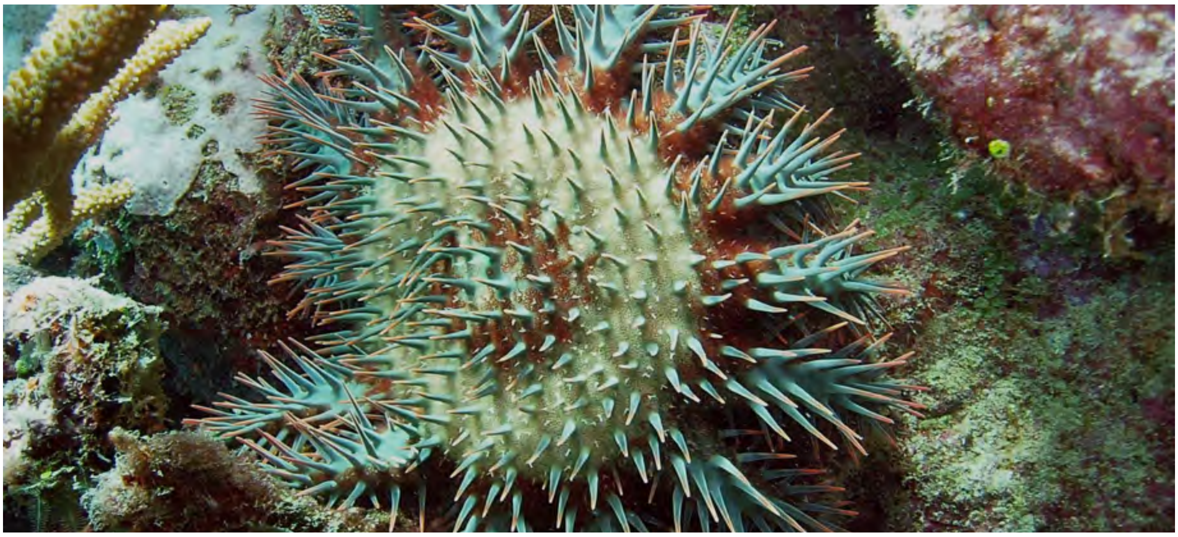
Evidence for recovery Recent analysis has shown significant declines in hard coral cover on the Great Barrier Reef (see Figure 2.5 and Figure 8.2).[39] However, there is evidence that healthy reefs can recover after disturbances at local scales.[54]

Reefs that are dominated by fast-growing coral species, such as the *Acropora*-dominated reef flats around the Keppel Islands, showed remarkably rapid initial recovery following substantial mortality induced by coral bleaching in 2006.[54] However, continued recovery has since been suppressed by a combination of exposure to flooding, minor storms and ongoing incidents of coral disease.[55,56] In 2012, the reefs in Keppel Bay were in poor condition, with little evidence of recovery, including little or no signs of recruitment (settlement of coral larvae and abundance of juvenile corals).[55]

This recent trend of declining recovery potential is evident along the inshore area from reefs in the Keppel Bay area to those adjacent to the Wet Tropics (Figure 8.2).[36] Despite evidence that inshore reefs had remained healthy over many hundreds of years prior to European settlement[57], these reefs are now being gradually but seriously damaged by disturbances occurring at a frequency that allows little or no time for recovery.[55] The decline in coral cover and lack of recovery coincides with degraded water quality as a result of land clearing, land use changes and agricultural use of the catchment.[57]

Average hard coral cover has declined; there is some evidence of recovery at a local scale.

The overall condition of inshore reefs in the Wet Tropics region has continued to decline from 2010 to 2013 (Figure 8.2).[36] The causes of this decline vary spatially. Some Wet Tropics sub-regions experienced high levels of coral disease in 2010 and 2011 which resulted in slow rates of coral cover increase that, in combination with crown-of-thorns starfish outbreaks, has reduced overall coral cover.[36] The density of juvenile corals has also declined to low levels.



Outbreaks of crown-of-thorns starfish are a major cause of reduced coral cover © Chris Jones

There are some examples of recovery from disturbance. For example, while coral cover is still very low in the Herbert Tully sub-region following the severe reductions caused by cyclone Yasi in 2011, increases in the density of juvenile corals indicates reefs are now showing some level of recovery.[36] Similarly, two and a half years after cyclone Yasi caused high to severe destruction on a number of reefs between Townsville and Cairns, reef health surveys found some mid-shelf and offshore reefs showing the promise of recovery, with moderate to high levels of small coral colonies evident.[58]

There is an overall, long-term decline in coral reef condition and resilience.

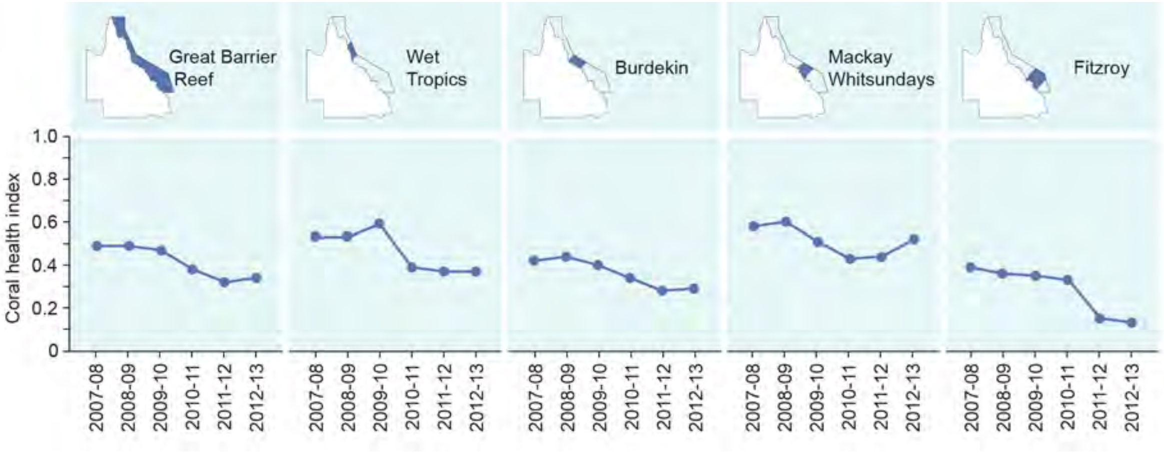


Figure 8.2 Changes in coral health of inshore reefs, 2008—2013
The coral health index aggregates cover of corals, cover of macroalgae, density of juvenile corals and the rate of coral cover increase. For corals to be considered in good or very condition, they would have a score of 0.6 or more. The figure presents information for inshore reefs only for the Reef as a whole and for the four areas indicated. Source: Reef Water Quality Protection Plan Secretariat 2014[59]

Despite some positive examples of recovery from disturbance, the overall trend for coral reef habitats within the Region is one of long-term decline in health and diversity[36,39,60,61] and therefore resilience. The causes include chronic disturbances such as poor water quality and outbreaks of coral disease, as well as a recent series of acute disturbances such as crown-of-thorns starfish outbreaks, coral bleaching events and cyclones[36,39,62,63,64], which have left insufficient time for many coral communities to recover between events (Figure 8.2). In addition to the disturbances mentioned above, at a local or individual reef level many lower risk threats, such as anchor damage and vessel groundings, can also impede recovery (see Section 9.3.7).

Frequent disturbances and chronic stresses reduce the potential for reef recovery.

Despite recent reductions in the loads of nutrients and sediments entering the Region (see Sections 3.3.1 and 7.3.11), there is a lag before improvements in catchment management translate into improved marine condition, particularly given the strong influence of extreme weather events in recent years. The projected vulnerability of coral reef habitats to changing climate variables (see Section 6.3.2), combined with other cumulative impacts, means coral reef habitats will face chronic effects plus more frequent and more severe disturbance events.[9,42,65,66,67] This will reduce their resilience.[15,68]

8.3.2 Lagoon floor habitats

There is limited information on the condition of the lagoon floor (see Section 2.3.6), although it is reasonable to assume that it varies considerably across the Region.

A range of activities can affect lagoon floor habitats including trawling, dredging, disposal and resuspension of dredge material, vessel anchoring and turbulence from both natural sources (for example storm and cyclone-driven wave actions)[69] and man-made sources (for example passage of vessel hulls and propellers close to the substrate).[70]

Trawling (see Section 5.4) has affected the lagoon floor over the past 40 years or more. The annual trawl fishing effort has remained stable over the past five years at levels that are about 40 per cent below the peak in 2005 (see Section 5.4).[71] However, in the past, trawling within the Region was more intense, and unsustainable practices led to concerns about impacts on seabed habitats.[72] The impacts of trawling and the recovery of the habitat following closures have been quantified for some areas of the Region and modelled for habitats down to 90 metres.[72,73,74] In general, on a Region-wide scale, current risk levels from trawling are generally low, but some risks (and concerns) remain.[71]

Dredging involves the extraction of parts of the lagoon floor to deepen an area and allow increased access for navigation and docking. It is usually associated with ports, shipping channels, marinas and boat ramps. Both capital (to permanently create, lengthen, widen or deepen areas) and maintenance (to ensure that previously dredged depths are maintained) dredging are undertaken at the majority of trading ports and a number of marinas within and adjacent to the Region (see Section 5.5). Projected economic and population growth in coming decades (see Chapter 6) demonstrates there will be a need for increased capital and maintenance dredging.

Trawling, port activities and anchoring affect the lagoon floor.

Once material is extracted from the lagoon floor during dredging, it requires disposal. This has generally been in reclamation projects or at sea[75], and some to land-based disposal sites. Between 2000 and 2013, the total volume of dredge material (from both capital and maintenance dredging) disposed in the Great Barrier Reef World Heritage Area was approximately 28 million cubic metres (see Figure 5.17).

The localised effects of dredging and disposal activities relevant to lagoon floor habitats are well documented and include: seabed disturbance[76]; removal or modification of habitats[77,78]; loss of species, including benthic organisms[75,79]; degradation of water quality[77,80] including increased turbidity levels[78]; and changes to hydrodynamics and coastal hydrology[78]. Less well understood are the broader regional and cumulative effects of sea disposal on inshore biodiversity.

There is little information about the threats posed by vessel anchoring or turbulence from the passage of vessel hulls and propellers close to the lagoon floor.

Management Potential threats to the lagoon floor are managed through a range of environmental regulations, policy and research. Spatially based protection measures include:

- Marine Parks zoning that continues to protect representative examples of all habitats within the Great Barrier Reef ecosystem, with a minimum of 20 per cent of each relevant bioregion protected and more than 30 per cent in highly protected areas. Zoning arrangements also restrict trawling to about one-third of the Great Barrier Reef Marine Park.
- One hundred and fifty-four ship anchorages designated adjacent to some of the ports along the Region's coast (see Figure 5.23). All but 12 are within the Great Barrier Reef Marine Park. Including swing room, the anchorages cover about 1200 square kilometres. They confine the impacts arising from anchoring for these ports.
- An increased number of Fish Habitat Areas have been declared in or adjacent to the Region to protect areas against physical disturbance from coastal development. Seventy areas now cover 880,000 hectares.[81] Some of these areas significantly restrict development activities while others allow for more flexible management.[82]

A range of environmental impact assessment processes and guidelines of the Australian and Queensland governments aim to minimise the impact of coastal development activities (for example dredging associated with port developments) on the seabed. However there have been increasing concerns about their effectiveness at identifying and managing for biodiversity impact.[83]

The 2014 *Queensland Ports Strategy*[84] will influence capital and maintenance dredging and dredge material disposal within, and adjacent to, the Region (see Section 5.5.1).

A 2012 ecological risk assessment examined the risks posed by the East Coast Otter Trawl Fishery to achieving fishery-related and broader ecological objectives of both the Australian and Queensland governments, including risks to the values and integrity of the Great Barrier Reef World Heritage Area.[85]

Evidence for recovery The Outlook Report 2009 concluded that some lagoon floor habitats previously at risk are recovering from disturbances. Full recovery will take decades.

There is evidence that lagoon floor habitats have the potential to recover from the impacts of trawling.[72,86] Rates of recovery vary and are correlated to the intensity of past trawling as well as the biology of the affected species.[72] Fan gorgonians recover slowly, while populations of hard coral such as *Turbinaria frondens* have been seen to recover within a couple of years.[72]

The resilience of trawled habitats in the Region varies.[85] A deepwater habitat was estimated to be at high risk from consistently high levels of trawl fishing effort. This deepwater habitat is known to support species such as champagne lobster, Balmain bugs, skates and rays as well as the target eastern king prawns. For other habitats, the assessment indicated they were mostly at a relatively low risk from trawling.

Some previously at-risk lagoon floor habitats are likely recovering.

Dredging permanently removes that portion of the seabed within the access channel and ongoing maintenance dredging means there is no opportunity for recovery of the area.

Dredged material is dispersed during the initial dredging and disposal activities, and may later be resuspended. A recent modelling study suggests dredge material placed at sea may have the potential to migrate over greater spatial and temporal scales than previously understood.[87] Although the results are preliminary they highlight the need for improved information to better understand the impacts on and potential recovery of seabed communities from disposal of dredge material at sea.

There is little monitoring of lagoon floor condition or recovery.

There is limited quantitative information regarding the recovery of lagoon floor habitats after disturbances. There is little or no monitoring of seabed condition except as required through permit approval conditions associated with development activities (for example ports and marinas).

8.3.3 Black teatfish

The black teatfish, a sea cucumber, fishery was closed to fishing in the Region following concerns for the long-term viability of the harvested stock.[88] At the time of closure in 1999, populations of the species were reduced by at least 75 per cent, with residual populations of approximately five individuals per hectare in harvested areas.[89] Since that report, there is little new information on black teatfish populations in the Region.

Management Management arrangements for the black teatfish are limited to environmental regulation activities. There is a fishery closure for the species and Marine Parks zoning protects a minimum of 20 per cent of each reef bioregion from extractive activities, including those containing suitable habitat for the species.

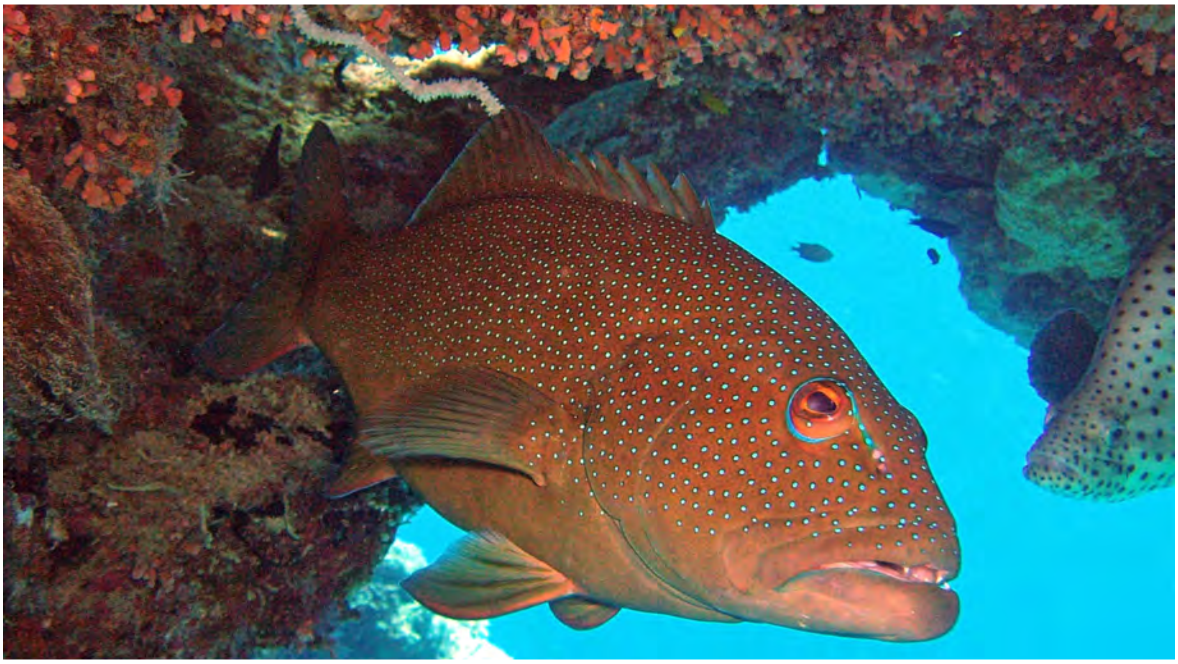
Recovery is likely to be slow for black teatfish.

Evidence for recovery As reported in the Outlook Report 2009, there was no evidence of recovery for the two years after the closure of the black teatfish fishery in 1999.[89,90] The lack of recovery was attributed to their life history characteristics, such as slow growth, limited migration and low recruitment.[89] It is also likely to be due to the fact that they need to be close to each other to achieve fertilisation after broadcast spawning, hence needing a critical population density for reproductive success.[90,91] The populations have not been resurveyed since 2002 and there is no estimate of current population densities. Recent modelling predicts a slow recovery for this species, and estimates the spawning biomass could potentially double by 2030.[88]

Recent fisheries management and monitoring of the black teatfish fishery in the Torres Strait may provide some indication of trends in the Region as the shallow-water black teatfish found in the Region behave similarly and may respond in a similar way. In the Torres Strait, the black teatfish fishery was closed in 2003, with no signs of recovery in surveys two years later.[92] However, when these surveys were followed up in 2010, the densities of black teatfish had increased significantly and were greater than those observed in 1995, well before the fishery closure.[93] Also the average size of the adults was larger than any previous survey carried out in the Torres Strait and the data indicates that these populations have recovered to near natural (unfished) densities over the seven years of the fishery closure, indicating a recovery period of between five and seven years for this fishery.[93]

8.3.4 Coral trout

Coral trout is the collective name for several species of predatory fish in the genus *Plectropomus*. They occur in coral reef and shoal habitats and feed on other fishes and invertebrates. The life history characteristics of each coral trout species differ, for example the timing and location of spawning, and this may influence their individual resilience.



Coral trout are a target for both commercial and recreational fishing © Chris Jones

Coral trout are very important species for both commercial and recreational fishers (see Section 5.4.1) and nearly all coral trout caught in Queensland are caught on the Great Barrier Reef. They have high commercial value and make up 54 per cent of the total catch within the Coral Reef Fin Fish Fishery, which took a total of 221 tonnes in 2011–12.[94] The retained recreational catch has been estimated to be between 200 and 550 tonnes over the last decade.[94,95] Currently more than 65 per cent of the Great Barrier Reef is open to hook and line fishing (including trolling), the technique most commonly employed to catch coral trout.

Extraction by legal fishing reduces the abundance of coral trout[96] and rapid local depletions of adults may occur under heavy fishing pressure. Between 1989 and 2003, 290 to 620 tonnes of coral trout were estimated to be discarded annually by the commercial Coral Reef Fin Fish Fishery on the Great Barrier Reef[97] with the ecological effect of such discards unknown. They are also subject to illegal fishing. The full extent and impact of illegal take on coral trout is unknown. However, reported incidents of illegal fishing in general are of concern, and in 2012–13 the proportion of these involving recreational fishers was more than one and a half times that in 2008–09 — partly due to an increased compliance focus on recreational fishing activity (see Section 5.4.3).

There are concerns for the condition of coral trout populations.

Issues regarding decreased abundance and adverse impacts of fishing on the Region's coral trout population, particularly at reefs near major population centres, have been reported since the 1970s.[98,99,100] Concerns have been raised recently about the status of coral trout populations in several areas.[101] Survey evidence suggests that coral trout stocks on some reefs had already been markedly depleted by 1984, well before the rezoning of the Great Barrier Reef Marine Park and the Great Barrier Reef Coast Marine Park in the early 2000s.[102]

The various threats from fishing are likely to be exacerbated by declines in coral reefs. Degradation of reefs will likely affect the abundance and diversity of prey species for coral trout.[103] Additionally, when the physical structure of reefs is changed — for example by severe weather events[63,104] — there are likely to be varying flow-on effects for different coral trout species including the availability of hiding places[105], settlement habitat for juveniles[105], and microhabitats for prey species[103]. Densities of coral trout in areas around the Keppel Bay islands declined more than 20 per cent following the 2006 coral bleaching event.[106]

Under climate change projections, sea temperatures will continue to rise and the frequency of coral bleaching events and the intensity of storms are expected to increase (see Section 6.3.1). In addition to effects through changes in their habitats, increasing sea temperature may reduce coral trout fertilisation success and affect larval development and survival.[107] Ocean acidification is likely to have serious implications for predator avoidance behaviour of coral trout larvae.[107]

Management A range of management arrangements (see Section 5.4.1) support the ability of coral trout populations to recover from disturbance.

The fishery focused on coral trout is primarily managed using the *Fisheries (Coral Reef Fin Fish Fishery) Management Plan 2003* and *Fisheries Regulation 2008*. Size limits for coral trout apply to all fishers and there are in-possession limits for recreational fishers. At least one species, the common coral trout, forms spawning aggregations around the new moons in spring, as water temperature warms.[108] In 2004, a total allowable commercial catch and three nine-day spawning closures during the spring new moons were introduced for coral trout. Significant reductions in the annual catch and the catch per unit effort since 2009 — indicative of a reduced coral trout population — have not triggered a reduction in the total allowable catch for the fishery, although this is under review. In addition, the spawning closures have been reduced to two five-day closures. The Queensland Government's stock status of coral trout moved from 'sustainably fished' to 'uncertain' in 2012 due to low catches and catch rates.[109]

Marine Park zoning complements fisheries management arrangements by excluding fishing from a representative portion of all reef habitats where coral trout live. Compliance patrols enforce the management arrangements.

Preliminary results of the inaugural stock assessment of coral trout being conducted by the Queensland Government and due for release in 2014 are indicating that, at the scale of the Region, the common coral trout population has a reasonable portion of its stock protected by zoning and is being fished at biologically sustainable levels in the areas open to fishing.

Coral trout habitat can be almost completely destroyed when reefs are exposed to the full force of severe cyclones

Evidence for recovery The ability of coral trout populations to recover from disturbances is influenced by key life history traits, such as growing rapidly in the first few years of life, maturing relatively early, variable timing of the change from female to male, having high annual fecundity, and spreading reproductive effort over space and time. In addition, some fisheries management measures are well matched to coral trout, for example conservative size limits for most coral trout species allow individuals to spawn for at least one season before they reach legal harvestable size.

Coral trout can recover quickly when disturbance is reduced.

When disturbance from fishing is reduced, coral trout numbers have recovered reasonably quickly, as demonstrated by the two-fold increase in their biomass in zones closed to fishing within two years of implementation of revised zoning arrangements in 2004.[106] Further work has confirmed this recovery has been maintained with coral trout generally found in greater abundance in no-take zones than fished zones (see Figure 2.10).[96]

Coral trout larvae from no-take areas disperse into other areas.

The zoning arrangements provide critical support to the potential for coral trout recovery and their overall resilience throughout the Region. For example, coral trout are generally larger in protected zones.[103] Size is especially important because larger fish produce disproportionately more larvae, improving overall reproduction within the population.[102,110,111] Increased reproduction within no-take zones appears to also benefit zones open to fishing. While many coral trout larvae in the Keppel Islands remain on their original reef, many others are dispersed, both to other no-take reefs and to reefs open to fishing.[112] An estimated 60 per cent of larvae on reefs open to fishing in the Keppel Islands area originated from reefs in protected zones.[112] Importantly, spatial analyses have shown that the design of the Great Barrier Reef zoning means that most reefs, open to fishing and no-take, are within range of dispersal from a no-take reef.[102,113,114] Thus, by maintaining connectivity between reefs, zoning has ensured they operate as a network, rather than in isolation — networks are recognised as more resilient than isolated components[2].

In 2009 cyclone Hamish damaged a large number of coral reefs within the Region, including many used by commercial fishers.[115] In 2011 cyclone Yasi also damaged reefs. In both instances one of the early hypotheses for the decline in commercial catch rates was that the cyclone increased mortality of coral trout. However, later work showed that adult fish were still present; it was their catchability that had been negatively affected.[104,115]

8.3.5 Loggerhead turtles

The breeding sites in the southern Great Barrier Reef (islands and cays of the Swain Reefs and Capricorn–Bunker Group) and the Bundaberg coast support the only significant stock of nesting loggerhead turtles in the South Pacific Ocean.[116,117] In the 1970s this area had an estimated population of 3500. By 2007, less than 300 breeding females were recorded, indicating a decline of 70 to 90 per cent. Various life history traits, including being long lived with slow growth rates, having delayed sexual maturity and high levels of egg and hatchling mortality, and inhabiting a range of habitats during their life stages, means it can take many decades for population decline or recovery to become evident.[118]

Management Loggerhead turtles continue to be protected under Commonwealth and Queensland legislation. Activities that threaten loggerhead turtles within the Region are managed through a combination of legislative requirements, operational policy and research addressing all known human-related pressures. Management actions specifically in place to protect loggerhead turtles include:

- Protection of the species under Commonwealth and Queensland environmental legislation, for example, ‘listed migratory species’ and ‘listed threatened species’ under the *Environment Protection and Biodiversity Conservation Act 1999* (Cth); ‘protected species’ under the *Great Barrier Reef Marine Park Regulations 1983* (Cth); ‘endangered’ under the *Nature Conservation Act 1992* (Qld).
- Identification of the incidental catch of sea turtles during coastal otter trawling and the ingestion of or entanglement in marine debris as key threatening processes under Commonwealth legislation. This is supported by: mandatory use of turtle excluder devices since 2001; mandatory vessel monitoring

The number of nesting loggerhead turtles is increasing

Threats to loggerhead turtles have been reduced in the Region

systems; mandatory reporting of interactions with species of conservation interest; and, from July 2014, actions to reduce marine debris impacts on marine turtles with funding from Reef Trust[119].

- Australian and Queensland government plans and strategies that integrate relevant information and help guide management activities, including the *Recovery Plan for Marine Turtles in Australia,* the *Great Barrier Reef Biodiversity Conservation Strategy 2013,* and *Back on Track Actions for Biodiversity.*[120,121,122,123,124,125]
- Spatial protection through zoning plans[126,127], a summer trawl closure in the Woongarra Marine Park (south of the Region) since 1991 and 'go slow' zones in Moreton Bay Marine Park — an important foraging area to the south of the Region.
- Baiting for foxes adjacent to nesting beaches in south-east Queensland.
- Research and monitoring of loggerhead turtles and their recovery including: the Sightings Network component of Eye on the Reef where marine turtle observations by community members and others are collected; Marine Wildlife Strandings program, which reports on marine turtle strandings and causes of mortality; and annual monitoring of nesting loggerhead populations along the Woongarra coast and in the Capricorn–Bunker Group in the south of the Region and of foraging populations in Moreton Bay to the south of the Region.

Loggerhead turtles are recovering; some threats remain.

Evidence for recovery As reported in the Outlook Report 2009, after the effective implementation of the mandatory use of turtle excluder devices on trawlers in 2001, the previous long-term decline in nesting loggerhead turtle numbers reversed to an increasing trend at all eastern Australian loggerhead turtle index beaches.[128] Mon Repos on the Woongarra Coast near Bundaberg is outside the Region; however, it is where the largest nesting aggregation for this stock occurs. During the 2011–12 nesting season, 377 nesting females were recorded nesting at Mon Repos (see Figure 2.12). This provides further evidence of a continued increasing trend in nesting females.[128]

Mandatory excluder devices have reversed a long-term decline in loggerhead turtles.

Despite the positive trend observed in nesting adults, significant pressures from death during incidental capture in pelagic long-line fisheries in the South Pacific outside Australian waters and ingestion of synthetic marine debris are thought to continue to affect this stock, especially the post-hatchling, juvenile and sub-adult life stages.[128] If the declines in juvenile and sub-adult life stages continue, then there may be a reduction in the number of nesting loggerhead turtles in another 20 or so years when they would have joined the breeding population.

8.3.6 Urban coast dugongs

The dugong population along the urban coast (south of Cooktown) is believed to be only a small fraction of pre-European levels.[129,130] Commercial harvest of the population ceased in 1969[131], but the legacy of this impact continues to affect the recovery and resilience of the population. Life history traits such as longevity, slow maturation, low reproductive potential, and dependence on inshore habitats make dugongs susceptible to a range of threats that affect their recovery.[132,133]

Dugongs are reliant on seagrass meadows that are susceptible to unfavourable environmental conditions.[134] At the Reef-wide scale, the extent of seagrass meadows was considered to be relatively stable at the time of the Outlook Report 2009. Since then some warning signs have emerged. Declines in some areas have been reported over recent years, as have significant losses of seagrass in the areas directly affected by the path of cyclone Yasi and large flood events.[134] Threats that affect seagrass, such as increased sediments and nutrients from land-based run-off, dredging and disposal and resuspension of dredge material, and physical damage to the seafloor, may have flow-on effects on dugongs.

Loss of seagrass from recent cyclones and floods has affected urban coast dugongs.

Direct threats to dugongs along the urban coast include incidental capture in commercial fishing and shark control program nets (see Section 5.4.3), illegal fishing nets and poaching (see Section 5.4.3), vessel strike, legal take (see Section 5.9) and ingestion of marine debris. Some Traditional Owner groups have voluntarily ceased hunting dugongs along the developed coast in recognition of the pressure this species is under from a range of other threats (see Section 5.9). It is unknown how projected increases in recreational use of the Region will affect dugongs.

Management A number of management measures to reduce the direct and indirect impacts on dugongs are in place in the Region, including:

- Protection of the species under Commonwealth and Queensland environmental legislation for example, 'listed migratory species' under the Environment Protection and Biodiversity Conservation Act; 'protected species' under the Great Barrier Reef Marine Park Regulations; 'vulnerable' under the Queensland Nature Conservation Act.
- Spatial protection of coastal and some estuarine areas through zoning plans, trawling closures, Dugong Protection Areas and Queensland Fish Habitat Areas.
- Traditional Use of Marine Resources Agreements and Indigenous Land Use Agreements.
- Improvement of water quality that enters the Region through the implementation of Reef Plan.
- Implementation of a dugong and turtle protection plan from July 2014, under the Australian Government's Reef Trust.
- Voluntary vessel 'go-slow' transit lanes in important dugong habitat in the Hinchinbrook area.

Since the Outlook Report 2009, based on evidence provided by the Marine Wildlife Stranding program, specific regulations were enacted to address deaths to dugongs from commercial nets in Bowling Green Bay.

Knowledge about the Region's dugong population continues to provide evidence for its condition. Specific programs include: the Sightings Network component of Eye on the Reef where dugong observations by community members and others are collected[135]; the Marine Wildlife Strandings program reports on dugong strandings and causes of mortality[136]; and regular aerial surveys to estimate dugong populations along the urban and remote coasts[137,138,139,140].

Evidence for recovery Population modelling suggests that even with the most optimistic combinations of life history parameters (for example, low natural mortality and no human-induced mortality), the dugong population is unable to increase by more than four to five per cent per year.[141]

The Outlook Report 2009 reported that the urban coast dugong population may take more than a century to recover and is subject to many continuing pressures. Dugong mortalities recorded by the Marine Wildlife Strandings program in 2011 were the highest since the commencement of the publication of the program's annual reports in 1998. The 2011 aerial survey results for the urban coast of Queensland showed the lowest recorded presence of dugongs since the surveys began in 1986 (see Figure 2.15).[137] This is in contrast to the previous survey in 2005, when the population was considered to have stopped declining.[137]

Urban coast dugong populations are the lowest since surveys began.

The recovery of dugong populations is strongly dependent on the condition of seagrass meadows, their primary food source, and reducing direct mortality, such as from incidental catch, marine debris and boat strike. Reducing fecundity is one response by dugongs to reduced habitat quality (available seagrass).[133,142] Significant losses of seagrass habitats were recorded following higher than average rainfall (and associated flooding) during the summer of 2010–11 and the category five cyclone Yasi in 2011.[143] The effects of these events were compounded by a number of previous years of extreme weather including cyclones and freshwater flooding.[144,145,146,147,148]

8.3.7 Humpback whales

Humpback whales were hunted extensively during the nineteenth and twentieth centuries, causing the global population to collapse to five per cent of its original size.[149] It is estimated that when the Australian east coast whaling industry ended in the 1960s, the east coast population of humpback whales had been reduced to a little over 500 individuals.

Management Banning whaling in Australian and international waters is the single largest contributing factor to the recovery of the humpback whale population in the Region. Management of other activities that threaten humpback whales within the Region is through a combination of legislative requirements, operational policy and research and monitoring.

The *Great Barrier Reef Marine Park Regulations 1983* specify minimum approach distances for vessels, aircraft and swimmers. Tourism operators are required to have a permit to operate within the Great Barrier Reef Marine Park, including to undertake whale watching. The Species Conservation

(Whale or Dolphin Protection) Special Management Areas are in effect for important areas, such as the Whitsundays. The Environment Protection and Biodiversity Conservation Act and *Nature Conservation (Wildlife Management) Regulation 2006* (Qld) continue to provide for complementary protection. A national recovery plan for humpback whales remains in effect across the nation.

In addition to legislation, a range of policies provide additional guidance and strategic direction to management operations. These include: *Action Plan for Australian Cetaceans; Australian National Guidelines for Whale and Dolphin Watching 2005; Operational Policy on Whale and Dolphin Conservation in the Great Barrier Reef Marine Park 2007*; and *Great Barrier Reef Biodiversity Conservation Strategy 2013*.

Knowledge and understanding about humpback whales continues to increase through a variety of actions including:

- Marine Wildlife Strandings program
- Australian Marine Mammal Centre, which coordinates Australia's marine mammal research expertise to provide scientific research and advice to underpin Australia's marine mammal conservation and policy initiatives
- the Sightings Network component of Eye on the Reef where humpback whale observations by community members and others are collected
- annual population surveys of the east Australian humpback whale population.

Humpback whales continue to show good recovery.

Evidence for recovery Annual recovery rates of the east Australian humpback whale stock have been estimated at between 10.5 and 12.3 per cent per year.[150] A survey in 2010 provides no evidence that the rate of population growth is slowing significantly and the re-estimation from these surveys sets growth between 10.5 and 11.3 per cent per year.[151] Assuming an average population growth trend of 11 per cent, it is calculated the population in 2013 was approximately 17,000 (Figure 8.3).

Humpback whale rolling near the surface

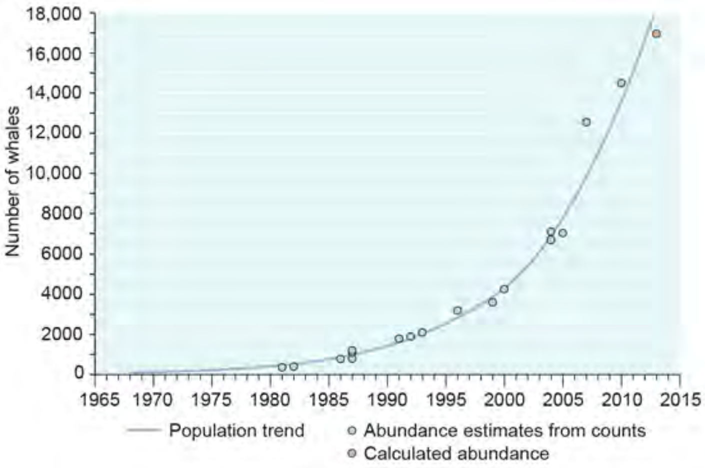


Figure 8.3. Recovery of the east Australian humpback whale population, 1981–2013
The east Australian humpback whale population (E1 stock) continues to strongly recover since whaling ceased in the 1960s. The 2013 data point is an estimate calculated using published population growth rate information[151]. Source: Adapted from Noad *et al.* 2008[150], Noad *et al.* 2011[151], Great Barrier Reef Marine Park Authority 2009[152]

8.4 Heritage resilience

Resilience is a concept yet to be widely applied in Australian heritage management.[153] The *Australia State of Environment Report 2011*[153] provides a broad-ranging assessment of the resilience of Australia's heritage. The following discussion is principally derived from that report.

8.4.1 Understanding heritage resilience

Broadly, heritage resilience is the ability of a heritage place, structure or value to experience impacts or disturbances while retaining the inherent heritage values for which it has been recognised.

The Region's heritage is susceptible to changes brought about by impacts from a range of sources. Its resilience can be considered in relation to both individual heritage values and the total heritage resource. The ability of individual places or the wider resource to withstand impacts depends on the nature of specific heritage values and their tolerance to change. For example, the resilience of a large geomorphological feature will be vastly different from the resilience of a small cultural site such as a fish trap or midden. In addition, while physical impacts may be important for the resilience of heritage places, impacts on intangible qualities such as the loss of knowledge or appreciation may be more important for cultural heritage values.

The resilience of the Region's heritage, while influenced by drivers such as climate change, population growth and economic development, is also strongly affected by knowledge, governance arrangements, resources and community attitudes.[153]

Resilience of heritage values will depend upon the nature and condition of the heritage value, the way it is valued, the use that is made of it, the impacts on it and the effectiveness of its management. In addition, the resilience of heritage values derived from the natural environment (such as Indigenous heritage values and world heritage values) is a direct function of the resilience of the underpinning natural values.

Factors affecting heritage resilience vary for different types of values.

Factors that affect heritage resilience may be considered at different levels. For example, individual heritage places may be highly susceptible to impacts such as floods and cyclones; however, the total natural or cultural resource base may be sufficiently robust to withstand the loss of individual places without substantive overall loss of heritage value.[153] For other heritage values, there may be only a few examples, making the overall value vulnerable to impacts.

The resilience of Indigenous cultural values is strengthened by the continuation of cultural practices and the retaining and creating of traditional ecological knowledge. Broader understanding and identification of the tangible and intangible aspects of Indigenous heritage values is also a critical component to improving its resilience. Some Great Barrier Reef Traditional Owners separated from land and sea country areas by European settlers are re-establishing connections to the ancestral lands by:

- undertaking on-country cultural camps
- promoting cross-generational knowledge sharing between knowledge holders (elders) and their youth
- cultural mapping of sacred sites, hunting and no hunting areas as well as turtle and dugong breeding and feeding grounds within their sea country areas
- surveys of burial sites, middens, birthing places, initiation sites, story places
- recording place names in traditional language.

Built heritage, such as lightstations, shipwrecks and buildings, are finite and irreplaceable — unlike a natural system, there is no capacity to regenerate. Such tangible heritage values, along with any associated intangible values of historic places, are generally more resilient where there is ongoing, relevant and viable use, and proactive management, including data collection, good conservation standards, regular maintenance and basic disaster planning.[153]

8.5 Case studies of improving heritage resilience

The three case studies below illustrate the likely resilience of some heritage values in the Region. They provide a more detailed analysis of the factors that contribute to resilience as described above. As knowledge improves additional case studies may be added in future reports.

The case studies presented are:

- cultural practices, observances, customs and lore
- lightstations
- underwater wrecks.

8.5.1 Cultural practices, observances, customs and lore

Indigenous heritage values are a major contributor to the heritage values of the Region (see Section 4.2). Traditional Owners are the custodians of these values and their resilience depends directly on the Traditional Owners and their connections to culture and sea country.

The Woppaburra people in the south of the Region are an example of a Traditional Owner group that has worked to improve the resilience of their cultural values by reasserting their cultural connections. They are the Traditional Owners of the Keppel islands and surrounding sea country. The name Woppaburra means 'Island People' or 'People of the Islands'. The area is their ancestral homeland and they continue to keep alive their customary obligations and connections to country, making the Indigenous heritage values associated with the island group strong and resilient.

Between 1865 and 1903, severe illness and inhumane treatment such as forced labour and murder resulted in the population of Woppaburra on the islands being reduced by about 75 to 80 per cent, from an estimated 60 to 80 individuals to just 17.[154] Predominantly only women and children remained, many suffering from ill health and poor treatment.[154] They were forcibly removed from their country and held in Aboriginal missions and reserves around Queensland.[155] Today, Woppaburra descendants number over 600, spread across five family groups living on the mainland.

Displacement of Traditional Owners from country affects the resilience of cultural heritage.

Management Woppaburra have been engaged in formal management arrangements for their sea country since June 2007, managing 561 square kilometres of the Great Barrier Reef Marine Park to achieve better environmental outcomes for themselves, their country, their Traditional Owner neighbours and the wider community.

Evidence for improvement Woppaburra are traditional knowledge holders with lifelong spiritual and physical connections to their land and sea country. They maintain strong connections with their country, despite the dispersal of their people from their ancestral homeland, the geographical location of their country and the complexity of contemporary management issues.[156] Woppaburra people often return to their ancestral homeland for knowledge sharing, and to undertake cooperative research, monitoring and hands-on management. They work cohesively as a group, communicating and negotiating with various stakeholders including neighbouring Traditional Owner groups, government agencies, educational institutions, museums and scientists to manage their estates for the protection of their living maritime culture. As a result, caring for the Keppel islands is now a shared responsibility amongst Traditional Owners and many other groups such as the island residents, tourism operators, recreational users, scientists and government management agencies.

Traditional Owners spending time on country is strengthening connections and transferring knowledge.

Woppaburra Traditional Owners are working to improve the resilience of their cultural values, North Keppel Island

8.5.2 Lightstations

Historic lightstations within the Region are a highly visible part of the maritime heritage of Queensland. The four lightstations recognised on the Commonwealth Heritage List have values which have been well surveyed and recorded. In contrast, the Pine Islet lightstation has fallen into major disrepair. Little is recorded of the heritage values of the remaining historic lightstations and aids to navigation in the Region.

Formal recognition of lightstation heritage values has improved their resilience.

Management Two of the four Commonwealth heritage-listed lightstations have heritage management plans completed for them. In addition, there is strong ongoing management for these sites, with annual inspections by qualified people, annual general maintenance plans, asbestos management plans and, in some cases, a permanent onsite presence. Other lightstations and aids to navigation are being well maintained as navigational facilities.

Evidence for improvement The four Commonwealth heritage-listed lightstations are appreciated by the community and there has been a recent emphasis on their restoration and maintenance. There is less public appreciation of the concrete 'tower' lightstations built in the Region in the 1920s and 1930s — any heritage values of which are not formally recognised. These structures are unlikely to be preserved for their heritage values beyond their working life without additional justification for preservation.

8.5.3 Underwater wrecks

Underwater wrecks, including historic shipwrecks and World War II wrecks, are a strong component of the heritage values of the Region. They are important both as individual wrecks, telling a particular story of endeavour and misfortune, and as a collection that improve understanding of the nation's history. The knowledge base for underwater wrecks is improving all the time.

Of the more than 1300 historic shipwrecks known to be in Queensland waters, the majority are likely to be located in the Region and new shipwrecks are discovered regularly (see Section 4.3.1). The wreck of the HMS *Pandora* has been well described and recorded. The same assessment cannot be made for many of the other shipwrecks in the Region. For example, while the HMCS *Mermaid* is recorded and within a protected zone, it is unsurveyed and deteriorating because it is located in a high-energy zone. There has been no baseline survey or any recovery and analysis of artefacts from the *Foam* and the SS *Gothenburg*. For hundreds of other shipwrecks, understanding, and hence protection, is lacking because they are yet to be located.

An estimated 140 submerged plane wrecks from World War II have not been located or recorded. Two wrecks, Catalina A 24 25 and Catalina A 24 24 which hold the remains of 25 personnel, were recently located 70 years after their presumed loss.

The community profile is strong for some wrecks. For the HMS *Pandora*, this is particularly so because its story is the centrepiece of the Museum of Tropical Queensland in Townsville. For the SS *Yongala*, some of the recovered artefacts are conserved and available for research and interpretation. There is also strong community recognition of the wreck as a world-famous dive site. As wrecks are discovered they become valued by the community, especially those people with personal connections to the wreck.

Management Ships, like the HMS *Pandora* and SS *Yongala*, greater than 75 years old, are protected under the *Historic Shipwrecks Act 1976* (Cth). In addition protected zones declared under the Act around some wrecks, for example a 500 metre protected zone declared around the HMS *Pandora,* further improves protection by strictly controlling access. There is little existing protection for other wrecks in the Region, including shipwrecks less than 75 years old.

Most underwater wrecks have poor resilience, particularly as they are poorly recorded.

Evidence for improving resilience In some cases, the resilience of a wreck's contribution to maritime heritage can be improved by recovering and preserving key artefacts and making them available. The HMS *Pandora* has been partially excavated, revealing a plethora of artefacts which have been conserved and are available for research, public display and interpretation, thus helping to improve understanding of the wreck and its heritage value.

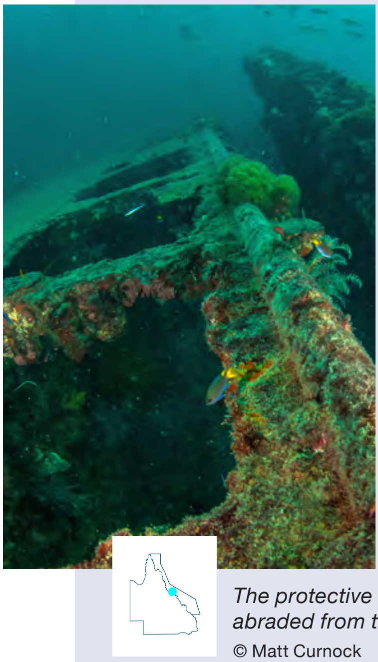
The HMS *Pandora* has remained physically stable due to its depth and the local sedimentary regime, and a layer of sediment makes the significant remaining material within the wreck relatively secure. On the other hand, the fabric of the wreck of the SS *Yongala* is above the seabed and therefore extremely vulnerable to cyclone damage, most recently during cyclone Yasi in 2011[157].

Underwater wrecks and their inherent heritage values are extremely vulnerable to unintended impacts such as anchor damage and marine debris from fishing activities. Most wrecks are not recorded, inspected, maintained or subject to dedicated regulatory protection. Some wrecks show signs of having been damaged by anchoring, trawling and recreational fishing.

The wreck of the SS *Yongala*

The SS *Yongala* — now a protected historic shipwreck with a 797 metre protected zone — sank in 1911 off Cape Bowling Green in the central Great Barrier Reef, with the loss of 122 lives. It was a coastal trader in the early twentieth century. The wreck is about 110 metres long lying in 30 metres of water on a relatively flat sandy seabed. It has historic, technical, social, archaeological, scientific and interpretive values. Added to its heritage significance, the wreck's structure provides a complex habitat for a wide variety of species and is a significant tourism destination.[157]

Cyclone Yasi significantly affected the wreck in 2011. The storm surge and associated churning sand abraded large sections of coral and other concretions off its steel hull. This calcareous layer was serving to reinforce and protect the wreck. The physical force of the storm and the movement of the sandy seafloor forced the ship to twist and move, causing the bow to drop onto the seafloor and the main deck section to partially collapse.[157] The damage inflicted is irreversible and will exacerbate deterioration of the wreck. Marine life is likely to re-establish and slow deterioration, however the wreck's ability to withstand future cyclonic events has been irreversibly compromised.[157]



The protective layer of marine life was abraded from the hull during cyclone Yasi
© Matt Curnock

8.6 Assessment summary — 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, and Section 116A(2)(c) of the *Great Barrier Reef Marine Park Regulations 1983* requires '… *an assessment of the current resilience of the heritage values*…' of the Region.

These assessments of ecosystem and heritage resilience are based on the information provided in earlier chapters of this report, namely the current state and trends of the Great Barrier Reef's biodiversity, ecosystem health and heritage values, as well as the trends in direct use, the factors influencing future values and the effectiveness of protection and management arrangements. A series of illustrative case studies provide additional information on:

- recovery in the ecosystem
- improving heritage resilience.

Over time, the case studies may be expanded or additional case studies developed.

8.6.1 Recovery in the ecosystem

Outlook Report 2009: Assessment summary
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.

2009 Grade	Current summary and assessment components	Assessment grade and trend				Confidence	
		Very good	Good	Poor	Very poor	Grade	Trend
🟦	**Recovery in the ecosystem:** Some disturbed populations and habitats have demonstrated recovery after disturbance (for example lagoon floor, loggerhead turtles, humpback whales). For some species recovery is not evident (black teatfish, dugongs) and is dependent on the removal of all threats. Increasing frequency and extent of some threats are likely to continue to reduce the resilience of species and habitats in the Region.			↓			
🟦	**Coral reef habitats:** Increases in frequency and severity of disturbances, such as cyclones, flooding, crown-of-thorns starfish outbreaks have reduced the capacity for coral reefs to recover since 2009. There is evidence of recovery at a local scale.			↓		●	◑
🟦	**Lagoon floor habitats:** Ongoing management arrangements mean that some lagoon floor habitats previously at risk are continuing to recover from disturbances. There is little monitoring of lagoon floor condition or recovery.		↔			◑	◑
🟩	**Black teatfish:** Based on recent modelling, populations of black teatfish in the Region are likely to be slowly recovering. Populations have recovered in Torres Strait.				↑	◑	◑
🟦	**Coral trout:** Coral trout populations demonstrate a strong ability to recover and increased reproduction in zones closed to fishing disperses beyond those zones. There are emerging concerns about the overall condition of coral trout populations.		–			◑	◑
🟩	**Loggerhead turtles:** Loggerhead turtle populations are recovering. There are comprehensive management arrangements in the Region, but some threats remain. Pressures from outside Australian waters are likely to influence their full recovery.			↑		●	●
🟩	**Urban coast dugongs:** The urban coast dugong population has declined further since 2009, affected by the loss of seagrass from cyclones and flooding. Continued effective implementation of all management arrangements is required to reduce direct threats.				↓	●	◑

8.6.1 Recovery in the ecosystem *continued*

2009 Grade	Current summary and assessment components	Assessment grade and trend				Confidence	
		Very good	Good	Poor	Very poor	Grade	Trend
🟦	**Humpback whales:** Humpback whales continue to recover at their maximum population growth rate 50 years after whaling stopped.	🟦 ↑				●	●

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.

Trend since 2009

↑ Improved
↔ Stable
↓ Deteriorated
▬ No consistent trend

Confidence

● Adequate high-quality evidence and high level of consensus
◐ Limited evidence or limited consensus
○ Inferred, very limited evidence

8.6.2 Improving heritage resilience

Outlook Report 2009: Not assessed

2009 Grade	Current summary and assessment components	Assessment grade				Confidence
		Very good	Good	Poor	Very poor	Grade
Not assessed	**Improving heritage resilience:** The resilience of built heritage values has improved where the values are well recorded and well recognised and there is strong regulatory protection and regular maintenance (for example heritage-listed lighthouses). The resilience of intangible values, such as many Indigenous heritage values, depends on the active involvement of the custodians of those values so that connections and knowledge are kept alive. Such involvement has continued to grow.		🟦			
Not assessed	**Cultural practices, observances, customs and lore:** Resilience of Indigenous heritage values depends on opportunities for Traditional Owners to access country and continue their cultural practices. Groups such as the Woppaburra in the south of the Region are working to strengthen cultural connections. Their aspirations are reflected in management arrangements such as the Traditional Use of Marine Resources Agreement.		🟦			◐
Not assessed	**Lightstations:** Formal recognition of the heritage values of the four major lightstations means there is comprehensive recording, restoration and regular maintenance. The heritage values of unlisted sites are less well known and more susceptible to being lost.		🟦			◐
Not assessed	**Underwater wrecks:** Most underwater wrecks are poorly recorded or their locations are unknown. Those that are comprehensively recorded and are within a protected zone have the highest resilience. In some cases heritage values can be protected by recovery and conservation of artefacts. Resilience varies depending on a wreck's physical situation.			🟩		◐

Grading statements

🟦 **Very good** Under current management, heritage values are well understood, well recorded and well protected. Actions are being taken to address major threats and restore values. Cultural connections and community awareness are strong.

🟦 **Good** Heritage values are described and recorded for many components. Many of the values are protected under current management arrangements. Some actions are being taken to address major threats and there is restoration work in some areas. Cultural connections are generally strong and there is some community awareness of values.

🟩 **Poor** Some of the heritage values are described and recorded, but most remain unrecorded and poorly understood. Some are protected under current management arrangements. The number of values where actions are being taken to address major threats and restore values is relatively small. Cultural connections have deteriorated. There is limited community awareness of values.

🟩 **Very poor** Heritage values are not well understood, recorded or protected. Few, if any, actions are being taken to address major threats and restore values. Cultural connections have deteriorated significantly and there is little community awareness.

Trend since 2009

New assessment for this report; no trend provided

Confidence

● Adequate high-quality evidence and high level of consensus
◐ Limited evidence or limited consensus
○ Inferred, very limited evidence

8.6.3 Overall summary of resilience

While the Great Barrier Reef Region may be one of the healthiest tropical marine ecosystems in the world, there is concern that its resilience is being seriously, and increasingly rapidly, eroded. There is no comprehensive information on the resilience of the Region's ecosystem — due largely to its size and complexity and the difficulties of measuring resilience. However, there is increasing evidence of loss of resistance and recovery capacity, although the extent of that loss varies considerably between ecosystem components and between localities. The natural resilience of the Region's values may be being overwhelmed by increases in levels of disturbance, and consequent impacts.

The emerging loss of ecosystem resilience is particularly critical in the context of the projected major increase in the effects of climate change impacts and the lag time between improved land management practices and observable ecosystem improvements. Current evidence suggests climate change trajectories remain on course for increasingly serious impacts in the Region. As these effects worsen, it is very likely that interactions between climate-related threats and other threats will have increasingly serious consequences. Managing for resilience is most important in situations where there is uncertainty about risks and appropriate management responses — the combined consequences of climate change and local and regional impacts on the Great Barrier Reef present such a situation. Maintaining the resilience of the Great Barrier Reef ecosystem will require major increases in effort to reduce local and global threats.

Resilience is a relatively new concept in heritage management, describing the ability of heritage values, both tangible and intangible, to experience impacts or disturbances while retaining the inherent values for which they are recognised. It depends upon the nature and condition of the values, the way they are appreciated and understood, the use that is made of them, the impacts affecting them and the effectiveness of management arrangements.

Built heritage values are finite and irreplaceable. Resilience is strongest for those places, structures and wrecks where: the structure and site are inherently stable; the values are well recorded, monitored and recognised; regulatory protection is in place and enforced; and planning, restoration and regular maintenance are undertaken. For such values in the Region, the four heritage-listed lightstations and the wreck of the HMS *Pandora* are likely to be the most resilient. Much of the remaining built heritage in the Region is likely to be less resilient because it is poorly recorded, rarely monitored or maintained, is not specifically protected or its significance is not well understood or appreciated.

The resilience of intangible values, such as many of the Region's Indigenous heritage values, depends strongly on the active involvement of the custodians of those values so that connections and knowledge are kept alive. Broader understanding of these values and having regulatory systems that recognise and take them into account are also important contributors to their resilience.

The resilience of heritage values derived from the natural environment (such as Indigenous heritage values and world and national heritage values) is a direct function of the resilience of the underpinning ecosystem.

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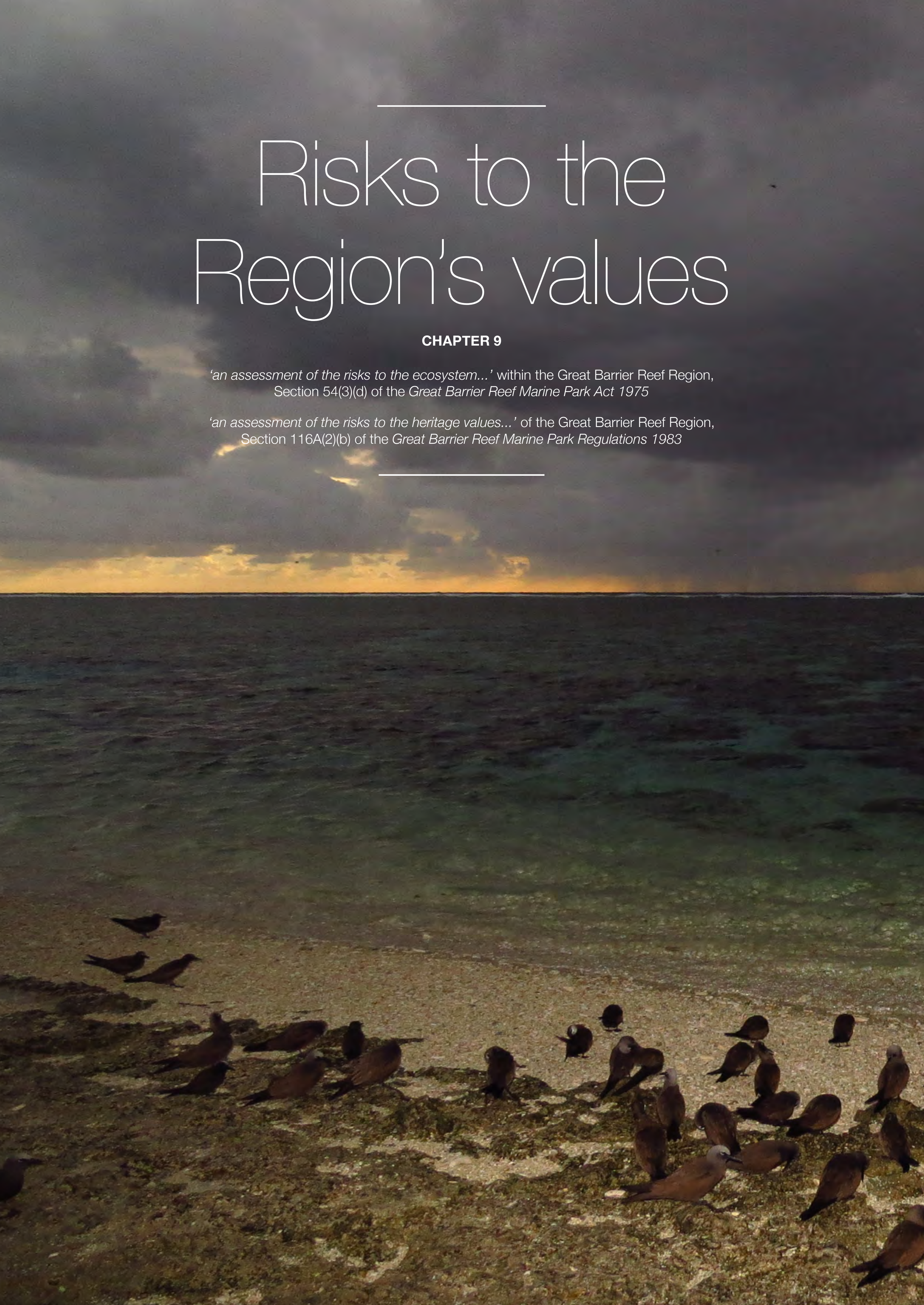

Risks to the Region's values

CHAPTER 9

'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*

'an assessment of the risks to the heritage values...' of the Great Barrier Reef Region,
Section 116A(2)(b) of the *Great Barrier Reef Marine Park Regulations 1983*

2014 Summary of assessment

Overall risk to ecosystem	The Region's ecosystem continues to be at serious risk and the threats likely to affect it in the future are increasing and compounding. The most serious risks arise from climate change, land-based run-off, coastal development and some aspects of direct use (particularly fishing). Other threats relating to direct use are more effectively managed and of less overall risk to the Reef.	🟧 ↑ ↑ High risk, Increased, Increasing
Overall risk to heritage values	The close connections between the Region's ecosystem and many of its heritage values mean that the projected risk of almost all threats is the same in both assessments. As a result, the most serious risks to the Region's heritage values are similarly climate change, land-based run-off, coastal development and some aspects of direct use.	🟧 ↑ High risk, Increasing

Full assessment summary: see Section 9.4

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Risks to the Region's values

9.1 Background

Outlook Report 2009: Summary of risks to the Reef

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 with catchment runoff, coastal development and some extractive use means that the nearshore environment next to developed areas is the most at risk.

Management of the Great Barrier Reef Region (the Region), including establishing future management priorities, focuses on addressing the threats predicted to be of greatest risk to the Region's values, but must also recognise the cumulative contribution of the full range of threats. It is informed by systematic assessments of the current and future risks presented by known threats, developed using the most up-to-date information.

The threats to the Region's values have changed over time.

The threats to the Region's values, and understanding of them, have changed over time. The development of a comprehensive management framework, integrated management arrangements and improved scientific knowledge reduced risk levels for many of the early identified threats. During the 1990s, management evolved to focus on emerging issues such as water quality, coastal development, fisheries, tourism and recreation.[1,2] The comprehensive risk assessment contained in the *Great Barrier Reef Outlook Report 2009*[3] identified climate change, land-based run-off, coastal development and some aspects of extractive use as the areas of most serious risk and has guided subsequent decision making and the setting of management priorities.[3,4] The impacts of climate change on the Reef ecosystem, linkages between terrestrial and marine systems, improvements in land-based run-off and cumulative impacts of coastal development and other activities have become key areas of additional management focus.

Threats to the Region's ecosystem and heritage values are assessed.

The risk assessment for threats to the Region's values described below is based on the information presented in the previous chapters. In addition to an examination of the level of risk various threats pose to the Region's ecosystem, which updates the assessment presented in the Outlook Report 2009, a new assessment looks at the risks those threats pose to the Region's heritage values.

9.2 Identifying and assessing the threats

9.2.1 Identifying the threats

The current and potential threats to the Region's ecosystem and heritage values considered in this risk assessment are based on the evidence presented in Chapters 5 and 6. The 41 threats considered are listed in Appendix 5, including a comparison with those assessed in the Outlook Report 2009. As far as possible, the threats and their descriptions are consistent with those used in 2009. The changes made reflect improved understanding of the threats affecting the Region's values and, in some cases, a merging of closely related threats. For key threats discussion is provided on post-2009 changes in risk where reasonable comparison is possible. Examples include illegal fishing and poaching (an amalgamation) and the now separate threats of dredging and disposal and resuspension of dredge.

Forty-one threats from all sources are assessed.

The threats identified are relevant to both the assessments of risks to the ecosystem and heritage values. Advice collected in 2013 from the Great Barrier Reef Marine Park Authority's Local Marine Advisory Committees, Reef Guardian councils, teachers from Reef Guardian schools, Reef scientists, as well as the outcomes of various community surveys were also considered in refining the set of threats.

An additional threat, 'incompatible uses', has been included in relation to heritage values to address the conflicts between uses that can arise. This threat is likely to be the result of many different direct uses of the Region and relates to activities undertaken that disturb or exclude other users. For example, where recreational use occurs in areas important for cultural activities, or where the nature of a commercial activity reduces access for recreational users.

The list of threats includes direct and indirect threats plus several 'consequential threats' that result from other threats. For example, the indirect threat of increased nutrients from land-based run-off affects the environmental process of primary production, which in turn can contribute to the threat of crown-of-thorns starfish outbreaks.[5]

It is important to note that the threats considered in this assessment can only be those that are known and identified. There are likely to be more unknown and unanticipated threats that have not been considered in the assessment. As these are identified they will be assessed in future reports.

Some threats have been combined and others added or redefined since the Outlook Report 2009 (Appendix 5).

Threats to the Reef from coastal development are part of the risk assessment

9.2.2 Assessing threats

Two separate risk assessments are presented, one for the Region's ecosystem and one for its heritage values. The Australian Standard for Risk Assessment (AS/NZS ISO 31000:2009)[6] was followed.

A standard risk assessment method is used, based on likelihood and consequence.

The likelihood and consequence of each threat are ranked on the five-point scale set out in Appendix 6. An overall risk level for each threat is determined, based on a combination of its likelihood and consequence. There are different criteria for ranking consequence in relation to the ecosystem and to heritage values. Risk is considered to be residual — that which remains once existing management has been taken into consideration.

The assessment is based on information in Chapters 2 to 8 of this report, including the current state of the Region's ecosystem and heritage values, current use patterns, factors influencing the Region's values, effectiveness of management and current resilience.

Because of the size and complexity of the Region and because many threats affect its values over different time and spatial scales, at different intensities and interact in many different ways, the assessment presented is high level. Several important broad assumptions were made in undertaking the assessment:

- Each threat was initially assessed in isolation from others; compounding effects are discussed separately (Section 9.3.7)
- Each threat was assumed to be possible at any geographic location within, or adjacent to, the Region
- 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.

In ranking the consequence of a threat to the ecosystem, variations in the extent of its likely effect are taken into account by having different criteria for broad-scale and local-scale effects (see Appendix 6). For each threat, the higher consequence grade is adopted in determining the overall risk.

For heritage values, definitions for consequence levels acknowledge variations in the extent of a threat's likely effect by encapsulating into a single criterion both the geographic scale of effects and the range of heritage values affected (see Appendix 6).

9.2.3 Understanding community views

The structured risk assessment process also takes into consideration input from Reef scientists and community views on the risks to the Great Barrier Reef. These were canvassed during 2013 through a number of avenues:

- As part of an Outlook scientific consensus workshop, 31 members of the Great Barrier Reef scientific community provided advice on likelihood and consequence for a supplied list of threats.[7]
- Respondents to national opinion survey[8] were asked to rank a provided list of threats.
- Residents of the Great Barrier Reef catchment as well as members of the fishing sector and the tourism sector (both tourists and tourism operators) were surveyed regarding the three most serious threats.[8]
- Members of the Great Barrier Reef Marine Park Authority's Local Marine Advisory Committees (32 respondents) as well as representatives of Reef Guardian councils (18 respondents) ranked a provided list of threats.
- Teachers from Reef Guardian schools completed an online survey and identified the five threats people should be keeping an eye on within the next five years and 25 years. Responses up to November 2013 (54 schools) are included.

Community views informed the risk assessment.

The outcomes of these surveys are summarised in Section 9.3.2.

Community views on risks to heritage values have not been surveyed.

9.3 Outcomes of risk assessment

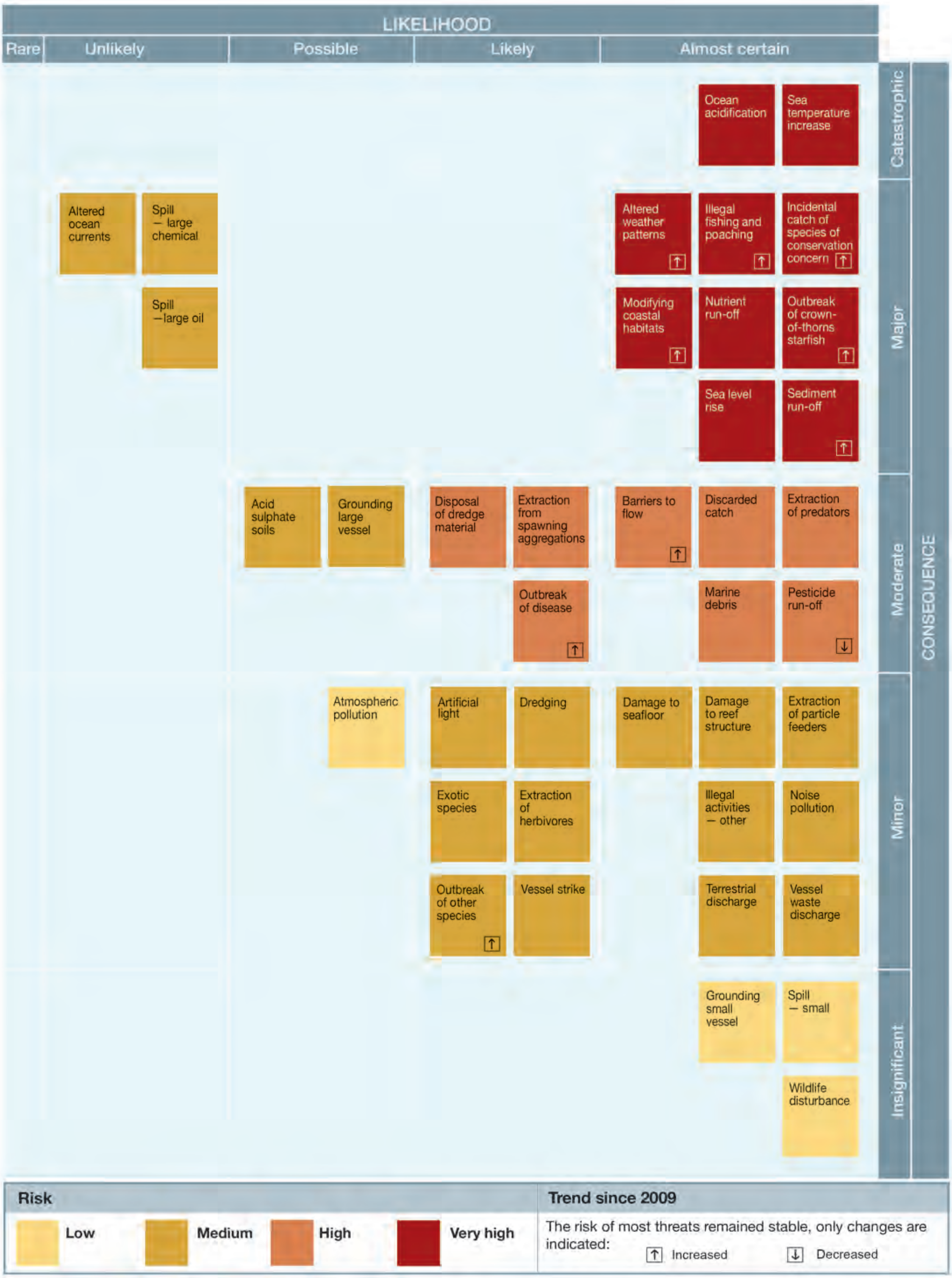
9.3.1 Level of likely risk

The outcomes of the risk assessment for the Region's ecosystem and heritage values are presented in Figure 9.1 and Figure 9.2 respectively. Appendix 7 provides a summary of the risk assessment of each of the 41 threats.

The close connections between the Region's ecosystem and its heritage values mean that the projected risk of almost all threats is the same in both assessments — although for some threats the likelihood of the threat having an effect and the consequence of the effect differ between the two assessments.

Two threats are assessed as presenting a different level of risk to heritage values compared to the ecosystem:

- Extraction of herbivores (excluding illegal fishing and poaching) is assessed as of lower risk for heritage values because, when performed by Traditional Owners, the activity has a positive effect on Indigenous cultural values.
- Wildlife disturbance is assessed as a higher risk for heritage values because predicted increases in use of the Region could cause increased localised effects on attributes specifically identified as contributing to the property's outstanding universal value such as the natural phenomena of seabird and marine turtle nesting. In addition, changes to animal behaviour caused by the presence of boats or people can change the nature of customary practice and change storylines, especially as the species disturbed are often totemic animals for Traditional Owners.



CONSEQUENCE / LIKELIHOOD	Rare	Unlikely	Possible	Likely	Almost certain
Catastrophic					Ocean acidification Sea temperature increase
Major		Altered ocean currents Spill — large chemical Spill —large oil			Altered weather patterns ↑ Illegal fishing and poaching ↑ Incidental catch of species of conservation concern ↑ Modifying coastal habitats ↑ Nutrient run-off Outbreak of crown-of-thorns starfish ↑ Sea level rise Sediment run-off ↑
Moderate			Acid sulphate soils Grounding large vessel	Disposal of dredge material Extraction from spawning aggregations Outbreak of disease ↑	Barriers to flow ↑ Discarded catch Extraction of predators Marine debris Pesticide run-off ↓
Minor			Atmospheric pollution	Artificial light Dredging Exotic species Extraction of herbivores Outbreak of other species ↑ Vessel strike	Damage to seafloor Damage to reef structure Extraction of particle feeders Illegal activities — other Noise pollution Terrestrial discharge Vessel waste discharge
Insignificant					Grounding small vessel Spill — small Wildlife disturbance

Risk

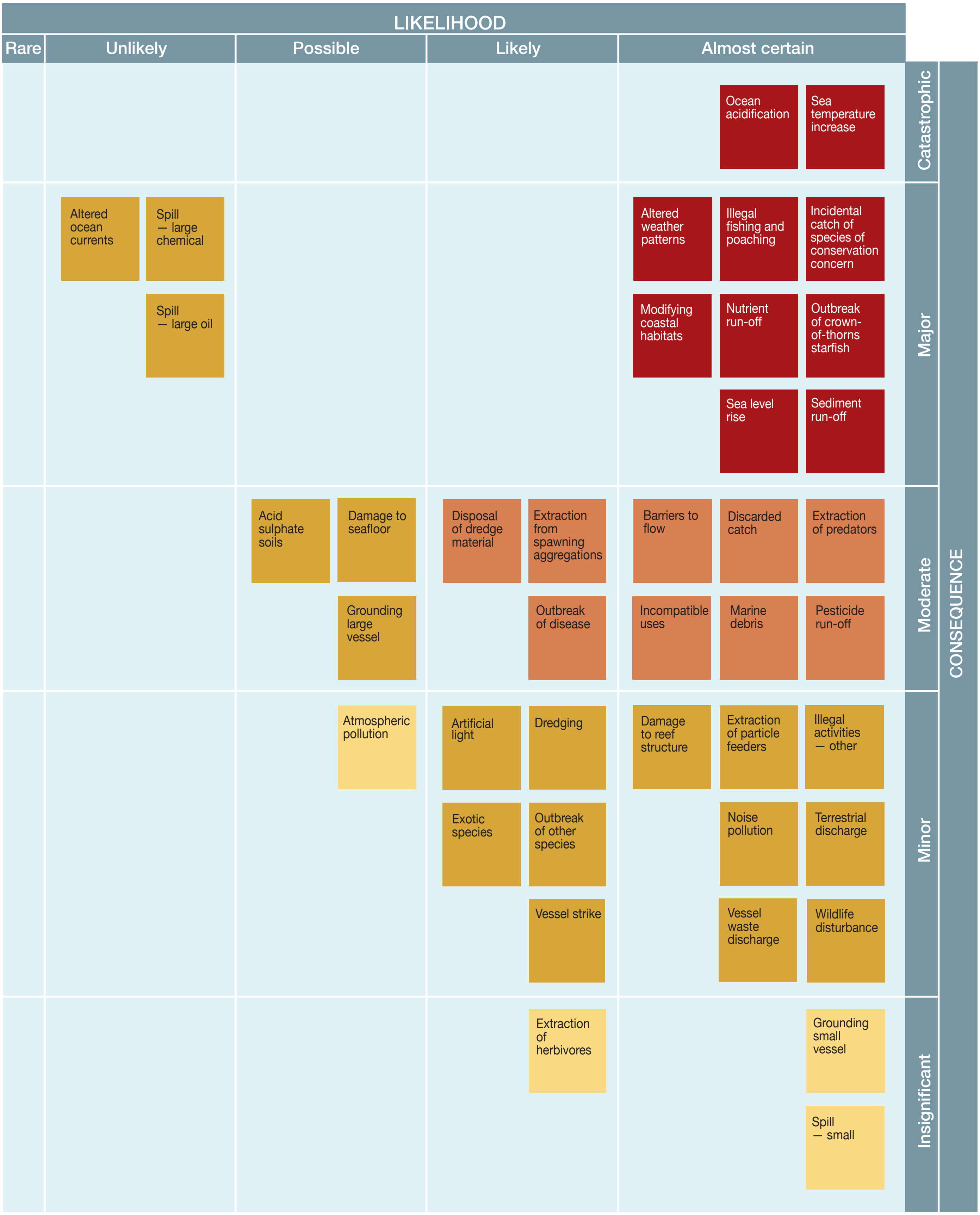
Low Medium High Very high

Trend since 2009

The risk of most threats remained stable, only changes are indicated: ↑ Increased ↓ Decreased

Figure 9.1 Risks to the Great Barrier Reef Region’s ecosystem

This risk matrix has been developed in accordance with the Australian Standard (AS/NZS ISO 31000:2009)[6] using terms and definitions detailed in Appendix 6. The assessment is based on current or documented future 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 5 and the assessment for each threat is summarised in Appendix 7.



	LIKELIHOOD				
CONSEQUENCE	Rare	Unlikely	Possible	Likely	Almost certain
Catastrophic					Ocean acidification Sea temperature increase
Major		Altered ocean currents Spill — large chemical Spill — large oil			Altered weather patterns Illegal fishing and poaching Incidental catch of species of conservation concern Modifying coastal habitats Nutrient run-off Outbreak of crown-of-thorns starfish Sea level rise Sediment run-off
Moderate			Acid sulphate soils Damage to seafloor Grounding large vessel	Disposal of dredge material Extraction from spawning aggregations Outbreak of disease	Barriers to flow Discarded catch Extraction of predators Incompatible uses Marine debris Pesticide run-off
Minor			Atmospheric pollution	Artificial light Dredging Exotic species Outbreak of other species Vessel strike	Damage to reef structure Extraction of particle feeders Illegal activities — other Noise pollution Terrestrial discharge Vessel waste discharge Wildlife disturbance
Insignificant				Extraction of herbivores	Grounding small vessel Spill — small

Risk	Trend since 2009
Low **Medium** **High** **Very high**	New assessment for this report; no trend provided

Figure 9.2 Risks to the Great Barrier Reef Region's heritage values
This risk matrix has been developed in accordance with the Australian Standard (AS/NZS ISO 31000:2009)[6] using terms and definitions detailed in Appendix 6. The assessment is based on current or documented future trends in the identified threats and existing management measures. The compounding effects of threats are not considered. Risks to heritage values were not assessed in the Outlook Report 2009. The full wording for each of the identified threats is provided in Appendix 5 and the assessment for each threat is summarised in Appendix 7.

9.3.2 Community views

Community views closely match the outcomes of the structured assessment.

The views of various community groups in relation to the most serious threats facing the Great Barrier Reef ecosystem are summarised in Table 9.1. Climate change, land-based run-off, shipping, port development, fishing, marine debris and pollution were common responses in many of the groups. This closely matches the outcomes of the structured risk assessment presented in Figure 9.1.

Similar to the community views presented in the Outlook Report 2009, climate change and land-based run-off continue to be viewed as the most serious threats. Community concern about some threats has increased (for example marine debris, shipping and port development).

Table 9.1 Community views on the threats facing the Great Barrier Reef ecosystem
A range of groups was canvassed about their views on threats to the Great Barrier Reef ecosystem. Various survey methods were used (Section 9.2.3). The responses were generally similar, with climate change and land-based run-off the threats most frequently highly ranked.

Community group	Ranking of perceived threats				
	First	Second	Third	Fourth	Fifth
Australians generally	Marine debris and beach litter	Climate change	Agricultural run-off	Shipping	Crown-of-thorns starfish
Reef catchment residents	Climate change/ global warming	Shipping	Agricultural run-off	Commercial fishing	Pollution
Tourists	Tourism	Climate change/ global warming	Commercial fishing	Shipping	Marine debris
Commercial fishers	Agricultural run-off	New ports and port expansions	Shipping	Natural disasters (floods, cyclones, earthquakes)	Government and regulation
Marine tourism operators	Climate change	Agricultural run-off	Boating / Shipping	Poor management/ over-management	New ports and port expansions
Scientific community	(in no particular order) Sediments and nutrients from land-based run-off; ocean acidification; sea temperature rise; climate change effects on ocean currents				
Local Marine Advisory Committees	Climate change effects on weather patterns	Clearing or modifying wetlands, mangroves and other coastal habitats	Disposal and resuspension of dredge material	Increased sea temperatures	Nutrients from catchment run-off
Reef Guardian councils	Climate change effects on weather patterns	Outbreaks of crown-of-thorns starfish	Nutrients from land-based run-off	Spill — large chemical	Sea temperature rise
Reef Guardian schools	(most mentioned) Climate change (including sea temperature rise and ocean acidification); water quality and land-based run-off; fishing; pollution; marine debris				

Community members identify land-based run-off as one of the key threats to the Reef

9.3.3 Sources, scale and timing

The identified threats to the Region's ecosystem and heritage values arise from a number of sources and are highly variable in both scale and timeframe. A better understanding of the individual threats is gained by linking them to their likely causes — the influencing factors identified in Chapter 6, including each of the direct uses — and by grouping them according to the likely timing and extent of their effect (Figure 9.3).

Some of the threats identified as highest risk are affecting the ecosystem and heritage values at a broad, often Region-wide, scale and are happening now (for example, the very high risk threats of sea temperature increase and nutrients and sediments from land-based run-off). Of the very high risk threats, ocean acidification and sea level rise are predicted to show major effects over a longer timeframe (within 10 to 20 years, see Section 6.3), although their effects are already beginning to be documented. The risks associated with a changing climate are likely to increase in the future due to emissions trajectories and an unavoidable lag effect where future change is locked in by past emissions.

The highest risk threats are on a Region-wide scale; most are already having an impact.

The threats that are more localised in their effects are generally rated as having a lower risk and are generally associated with direct use of the Region. Nevertheless, some risks associated with some threats remain high at local or regional scale, as is the case for pesticide run-off.[9]

Coral bleaching is one of the effects of increases in sea temperature

9.3.4 Highest risk threats

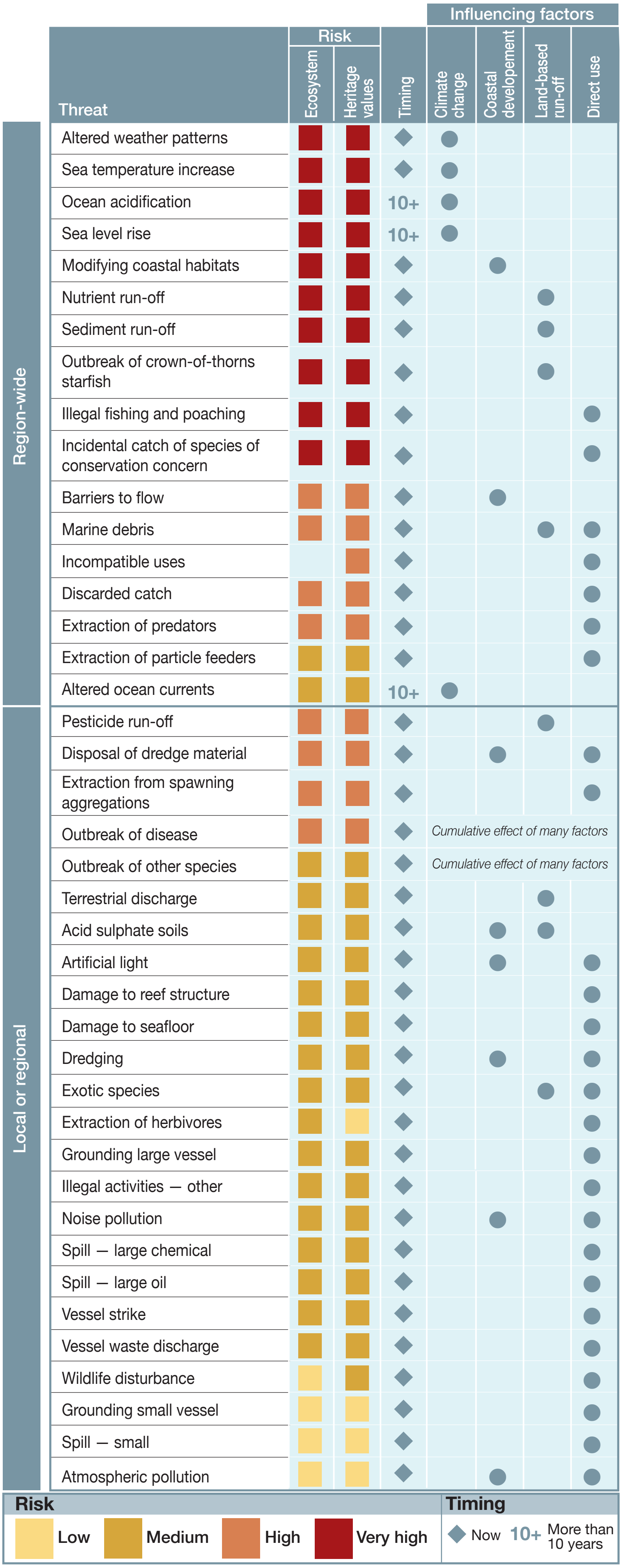
Based on assessments of the 41 identified threats (Figure 9.1 and Figure 9.2), 10 threats present a very high risk to the Region's ecosystem and heritage values. A further eight and nine threats present a high risk to the Region's ecosystem and heritage values, respectively. The threats assessed as very high and high risk (grouped by influencing factor) are:

- **climate change** — sea temperature increase; altered weather patterns; ocean acidification; and sea level rise
- **coastal development** — clearing and modifying coastal habitats; artificial barriers to flow; and disposal and resuspension of dredge material
- **land-based run-off** — nutrients from run-off (including its links to outbreak of crown-of-thorns starfish); sediments from run-off; pesticides from run-off; and marine debris
- **direct use** — illegal fishing, collecting and poaching; incidental catch of species of conservation concern; marine debris; incompatible uses (assessed for heritage values only); effects on discarded catch; retained take (extraction) of predators; disposal and resuspension of dredge material; and retained take (extraction) from unidentified or unprotected spawning aggregations.

The highest risk threats arise from climate change, coastal development, land-based run-off and some aspects of direct use.

Outbreaks of disease, both naturally occurring and introduced, are also assessed as a high risk. Such outbreaks are likely to be an indicator of overall stress in the natural system from the accumulation of impacts arising from many influencing factors.

The lack of understanding of the extent and location of many heritage values (for example wrecks and archaeological sites) means that the risks to heritage values associated with dredging, disposal of dredge material and damage to the seafloor in non-reef areas may be underestimated. A direct interaction with relevant activities may cause significant or permanent damage to sites of particular cultural or historical importance. Assessment processes required during permitting of these activities mitigate this risk, but only for identified values.



	Threat	Risk		Timing	Influencing factors			
		Ecosystem	Heritage values		Climate change	Coastal developement	Land-based run-off	Direct use
Region-wide	Altered weather patterns	🟥	🟥	◆	●			
	Sea temperature increase	🟥	🟥	◆	●			
	Ocean acidification	🟥	🟥	10+	●			
	Sea level rise	🟥	🟥	10+	●			
	Modifying coastal habitats	🟥	🟥	◆		●		
	Nutrient run-off	🟥	🟥	◆			●	
	Sediment run-off	🟥	🟥	◆			●	
	Outbreak of crown-of-thorns starfish	🟥	🟥	◆			●	
	Illegal fishing and poaching	🟥	🟥	◆				●
	Incidental catch of species of conservation concern	🟥	🟥	◆				●
	Barriers to flow	🟧	🟧	◆		●		
	Marine debris	🟧	🟧	◆			●	●
	Incompatible uses		🟧	◆				●
	Discarded catch	🟧	🟧	◆				●
	Extraction of predators	🟧	🟧	◆				●
	Extraction of particle feeders	🟨	🟨	◆				●
	Altered ocean currents	🟨	🟨	10+	●			
Local or regional	Pesticide run-off	🟧	🟧	◆			●	
	Disposal of dredge material	🟧	🟧	◆		●		●
	Extraction from spawning aggregations	🟧	🟧	◆				●
	Outbreak of disease	🟧	🟧	◆	*Cumulative effect of many factors*			
	Outbreak of other species	🟨	🟨	◆	*Cumulative effect of many factors*			
	Terrestrial discharge	🟨	🟨	◆			●	
	Acid sulphate soils	🟨	🟨	◆		●	●	
	Artificial light	🟨	🟨	◆		●		●
	Damage to reef structure	🟨	🟨	◆				●
	Damage to seafloor	🟨	🟨	◆				●
	Dredging	🟨	🟨	◆		●		●
	Exotic species	🟨	🟨	◆			●	●
	Extraction of herbivores	🟨	⬜	◆				●
	Grounding large vessel	🟨	🟨	◆				●
	Illegal activities — other	🟨	🟨	◆				●
	Noise pollution	🟨	🟨	◆		●		●
	Spill — large chemical	🟨	🟨	◆				●
	Spill — large oil	🟨	🟨	◆				●
	Vessel strike	🟨	🟨	◆				●
	Vessel waste discharge	🟨	🟨	◆				●
	Wildlife disturbance	⬜	🟨	◆				●
	Grounding small vessel	⬜	⬜	◆				●
	Spill — small	⬜	⬜	◆				●
	Atmospheric pollution	⬜	⬜	◆		●		●

Risk ⬜ Low 🟨 Medium 🟧 High 🟥 Very high

Timing ◆ Now 10+ More than 10 years

Figure 9.3 Summary of threats arising from factors influencing the Region's values, and associated scale and risk level

The figure links threats with the key factors (see Chapter 6) of most influence on them either directly or indirectly. Instances where a factor is likely to be only an insignificant influence on a threat are not displayed. Risk level for each threat is also shown, along with the scale at which the effects of the threat are expected to occur. The figure shows that threats assessed as very high risk to the Region's values are expected to have an effect over a broad or Region-wide scale and most are already having an effect.

9.3.5 Trends in risks to the Region's values

The assessed risk for a number of the threats to the Region's ecosystem has changed since the assessment presented in the Outlook Report 2009. These variations are indicated in Figure 9.4. The risks to heritage values were not assessed in 2009.

Increases in assessed risk Generally, increases in the risk grade have been the result of increased understanding of the threat, its distribution and the likely severity of its consequences. For example, in 2009 the risk associated with sediments in land-based run-off was assessed as high (likelihood: almost certain, consequence: moderate), but is now assessed as very high (likelihood: almost certain, consequence: major) based on improved understanding of both the distribution and effects of sediments in the marine system and the likely lag time between decreases in the loads entering the Region and improvements in the Region itself[10] (see Section 3.2.4). Similarly, improved understanding of crown-of-thorns starfish outbreaks (see Section 3.6.2), their frequency, causes and effects, has increased the grading of this threat since the Outlook Report 2009. The resulting risk has increased from high to very high. Increases in the assessed risk of clearing and modifying coastal habitats (from high to very high) and artificial barriers to flow (from medium to high) are a reflection of improved understanding of the importance of healthy habitats and ecosystem processes in coastal areas adjacent to the Region (see Section 3.5).

The risk presented by altered weather patterns has also increased since 2009: partly because the threat definition has been broadened from just cyclones to effects on weather more generally; and partly because of improved understanding (see Sections 3.2 and 6.3). Knowledge in this area has grown through both research associated with the extreme weather experienced since 2009[11] and longer term studies demonstrating the significance of extreme weather in shaping the ecosystem[9,12,13].

The risks associated with an outbreak of disease or species other than crown-of-thorns starfish have increased, mostly due to a decline in the overall condition of the ecosystem, making such outbreaks more likely and of greater significance (see Section 3.6.1).

Incidental catch of species of conservation concern has an increased level of risk in the current assessment compared to 2009. The move from high to very high reflects improved knowledge about which species are at risk and the implications for some species of even small numbers of deaths (see Chapter 2 and Section 5.4).

Illegal fishing and collecting was assessed separately from illegal poaching in 2009, but these illegal extraction activities are now considered as a group. The risk of illegal poaching of species such as dugong and turtles is likely to have decreased since the Outlook Report 2009 because of its focus in management (see Sections 5.9.3 and 7.4.2). However, the risk associated with illegal fishing and collecting has increased (see Section 5.4.3). The risk grading of very high recognises the serious effects illegal extraction has on the resilience of the ecosystem and reducing the effectiveness of management actions implemented for biodiversity protection.

Reductions in assessed risk Improved understanding of the distribution of pesticides in the Region[9] (see Section 6.5.1) and of the effects of pesticides on both inshore habitats and adjacent coastal habitats (with flow-on effects on the Region's values) has decreased the assessed risk associated with pesticides in land-based run-off from very high to high.

↑	**Increased risk**
🟥	Altered weather patterns
🟥	Illegal fishing and poaching
🟥	Incidental catch of species of conservation concern
🟥	Modifying coastal habitats
🟥	Outbreak of crown-of-thorns starfish
🟥	Sediment in land-based run-off
🟧	Barriers to flow
🟧	Outbreak of disease
🟨	Outbreak of other species
↔	**No change in risk**
🟥	Nutrients in land-based run-off
🟥	Ocean acidification
🟥	Sea level rise
🟥	Sea temperature increase
🟧	Discarded catch
🟧	Extraction from unprotected spawning aggregations
🟧	Extraction of predators
🟧	Marine debris
🟨	Altered ocean currents
🟨	Damage to reef structure
🟨	Damage to seafloor
🟨	Extraction of herbivores
🟨	Extraction of particle feeders
🟨	Grounding large vessel
🟨	Introduction of exotic species
🟨	Spill — large chemical
🟨	Spill — large oil
🟨	Vessel strike
🟨	Vessel waste discharge
⬜	Grounding small vessel
⬜	Spill — small
↓	**Decreased risk**
🟧	Pesticides in land-based run-off

Risk

⬜ Low 🟨 Medium 🟧 High 🟥 Very high

Figure 9.4 Trends since 2009 for threats to the Region's ecosystem
The figure shows the changes in the outcomes of the risk assessment compared to 2009. Nine threats are assessed as having a higher risk than in 2009. Only one threat has a lower risk grading — pesticides in land-based run-off —because more is now known about its effects and spatial extent. Threats that were not assessed in the Outlook Report 2009 or were grouped differently do not appear in this comparison figure.

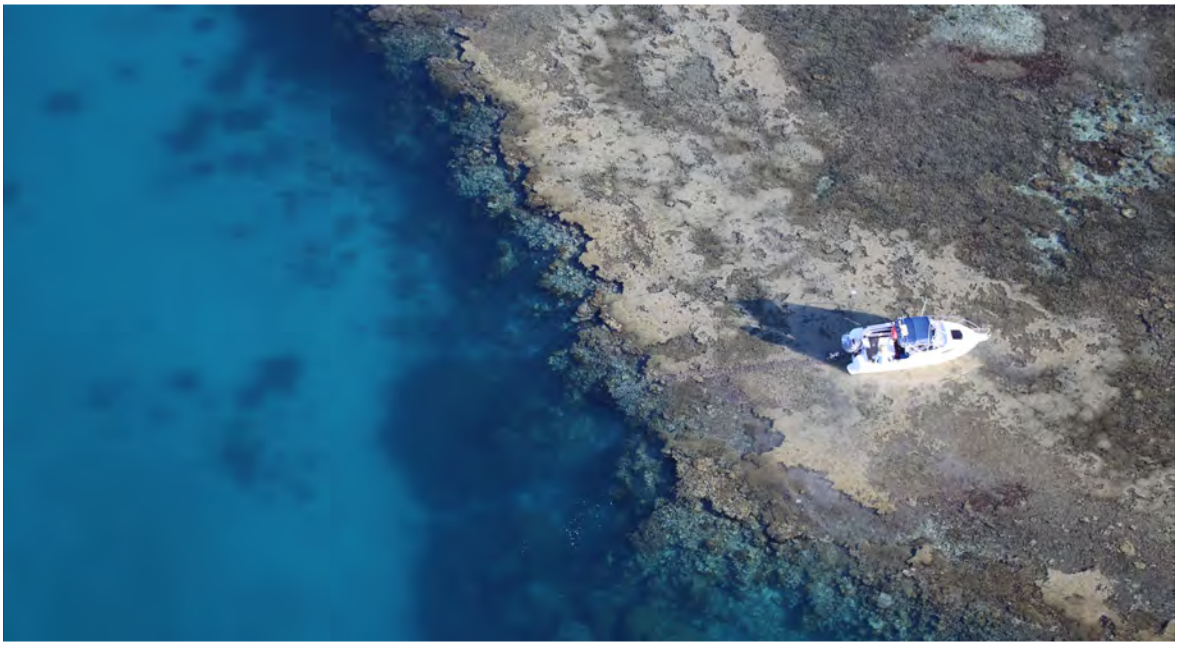
Unchanged risk levels Notably, the risks associated with some threats have remained the same despite an increase in the causes of the threats. For example, because of improvements in the management of shipping in the Region (both implemented and pending as outlined in the draft North-East Shipping Management Plan), the likelihood of a serious shipping incident such as a large vessel grounding or a large oil and chemical spill has remained unchanged, despite the significant increase in shipping traffic (see Sections 5.8 and 7.3.7).

The continued strong management of direct uses such as commercial marine tourism has resulted in associated threats, such as small vessel grounding and damage to reef structure from anchoring, snorkelling and diving activities, remaining unchanged (see Section 7.3.1).

For some threats, management changes have kept the risk stable.

The risks associated with the legal extraction of the Region's resources (for example herbivores and predators) have remained stable overall. For the threat of extraction of predators, the assessed risk is stable; the threat is a combination of two previous threats — extraction of top-order predators and extraction of lower order predators.

There is a worldwide increase in marine debris and increased understanding of domestic contributions and dispersal (see Section 6.6.2). The risk to the Region's values from marine debris continues to be high and is unlikely to decrease in the immediate future.



The overall risk to the Reef from small vessel groundings remains low

Undetermined changes in risk Dredging and disposal threats were considered together in 2009. These risks were separated for this assessment given the different management approaches and understanding of the effects of each activity. Historically, capital dredging activities did not occur every year. While the permitted amount of dredging has increased since the Outlook Report 2009 and is projected to continue to increase in the coming decade, its consequences to the Region's ecosystem are constrained to the area around the dredged footprint. The frequency of disposal and resuspension of dredge material (from both capital and maintenance dredging) is likely to increase with continued development and expansion of ports in the coming decade. The risk level of 'high' for disposal and resuspension reflects increases in the likely future trends in volume of material requiring disposal, uncertainty of its potential effects on the ecosystem, and the need for strengthened monitoring of the effects of this threat (see Sections 5.5, 6.6, 7.3.4).

9.3.6 Effectiveness at managing threats

As was the case in the Outlook Report 2009, the origins of many of the highest risk threats are outside the Region (either global or within the Great Barrier Reef catchment). The effectiveness of their management (Figure 9.5) was independently assessed as some of the weakest, especially in terms of outcomes (see Chapter 7).

Overall risk associated with climate change and land-based run-off has remained very high and high, respectively, since 2009. The effectiveness of management in relation to climate change has weakened in relation to context, planning, inputs, processes and outcomes (see Section 7.3.9), while positive gains have been made in planning, processes and outputs for management around land-based run-off (see Section 7.3.11).

The overall risk associated with coastal development has increased since 2009 because the implications and extent of several key threats (for example modifications to coastal habitats) are now better understood. However, the effectiveness of management in relation to coastal development has not improved overall (see Section 7.3.10).

The overall risk associated with direct use is medium – noting that, as in 2009, fishing stands out as being associated with several threats considered to be high and very high risk. Increased management attention to the remaining impacts of fishing has not yet significantly reduced risk levels (though understanding has improved). There have been reductions in resourcing for fisheries management with flow-on effects on monitoring and reporting. Trawling is known to present significant risks for deep-water skates, several rays and sea snakes, and there is the capacity for trawl activity to increase under existing management arrangements. Additionally, an increase in coastal population and changing demographics could lead to increased risk from recreational fishing, especially given recent information on non-compliance rates (see Section 5.4.3).

Port activities are the largest contributor to dredging and disposal of dredge material in the Region (with tourism developments usually a smaller contributor). Proposals to dispose of dredge material on the seafloor are projected to increase with continued port development. The consequences for biodiversity and some heritage values within the footprint of dredging sites are serious and possibly irreversible. There is emerging concern that resuspension of sediment could affect the condition of values over a broad scale and long timeframes (see Section 5.5), adding further pressure to already declining inshore ecosystems and affecting aesthetic beauty and cultural practices.

Management is least effective for some of the highest risk areas.

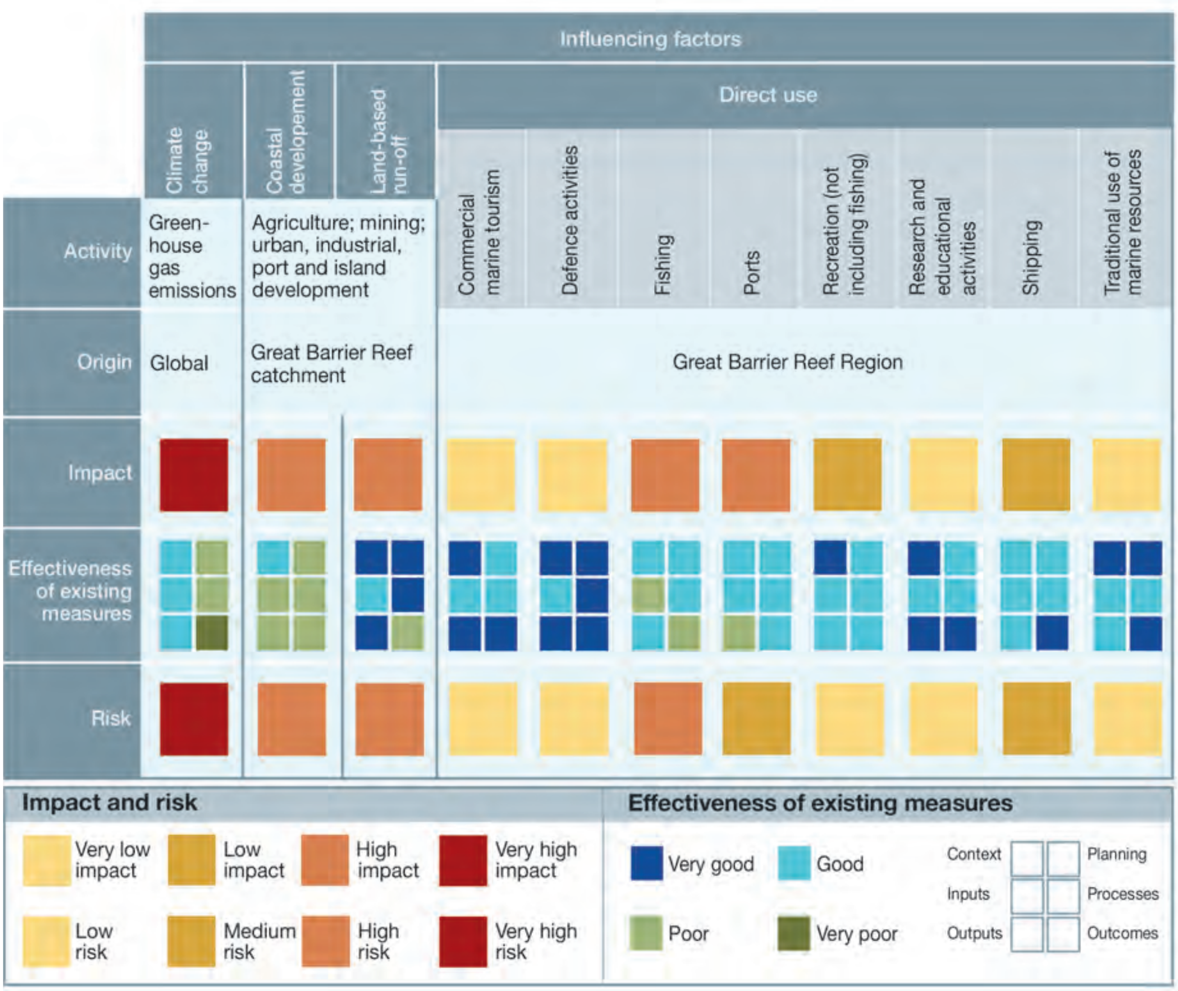


Figure 9.5 Management effectiveness, impacts and risk associated with factors influencing the Region's values
Impact grades (Chapters 5 and 6), the effectiveness of current protection and management (Chapter 7), and overarching risk levels are shown for factors influencing the Region's values, including for component activities of direct use. The influencing factors that present the highest overall risk to the Region's values have their origins outside the Region. Higher risk also corresponds with uses and influencing factors that have both higher impact on values and weaker management effectiveness. The effectiveness of management was 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) — see Chapter 7 for a full discussion. 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.

9.3.7 Cumulative impacts

The assessments of individual risks presented in Figure 9.1 and Figure 9.2 do not take into account the cumulative impact of the threats on the Region's ecosystem and heritage values. None of the threats operate in isolation. They are connected through the geographic areas in which they occur (Figure 9.6), the timeframes in which they act, and the habitats, species, ecosystem processes and heritage values they affect.

Interactions between threats can have variable effects. Many of the threats considered in this report are likely to have synergistic effects, where the impact of two or more threats acting together is much worse than that expected from the sum of their individual impacts.[14,15,16]

An analysis of cumulative effects takes into account direct, indirect and consequential impacts and the incremental and compounding effects of these threats over time, including past, present and reasonably foreseeable future pressures.

The independent assessment of management effectiveness[17] for the Outlook Report 2009 identified the extent to which cumulative impacts are being addressed as the weakest indicator across the entire management effectiveness assessment. It concluded that management effectiveness challenges were most evident for those issues which were broad in scale and complex socially, biophysically and jurisdictionally. The independent assessment of management effectiveness for this report (Chapter 7) highlighted that managing agencies' understanding of cumulative and consequential impacts is improving, although this remains problematic for most issues especially in achieving outcomes for fishing.

There are several ways to consider the cumulative effect of threats upon the Region's ecosystem or heritage values. It largely depends on the context for which the examination is occurring and the amount of evidence available for the assessment. Methods range from modelling approaches that use simple, unstructured lists to quantitative mathematical models or spatial approaches that focus on a specific location or component of the ecosystem.

Figure 9.6 Example of multiple threats to the ecosystem within an area
Multiple threats, including those presenting high and very high risks to the Region's values, can overlap and interact within an area. They combine to present a serious cumulative risk to local habitats and species.

Another way to consider the cumulative effect of threats is by examining a particular component of the ecosystem or a distinct heritage value, for example coral reef habitats (Figure 9.7). This has generally been done previously at a single species level.[18,19] More recently, qualitative models developed for the Region have provided an initial assessment of some of the complexity associated with understanding cumulative effects on coral reef habitats.[16] The model shows some cause-and-effect relationships are relatively simple, such as an increase in ocean warming making coral bleaching events more frequent, which then leads to a reduction in hard coral cover. However, other relationships are much more complex. For example, an increase in land-based run-off from agriculture drives four threats identified in the model (toxins, nutrients, turbidity and sedimentation), in turn affecting seven ecosystem variables (predatory fish, herbivorous fish, crown-of-thorns starfish, fish and invertebrates, macroalgae, crustose coralline algae and coral recruitment, and coral cover).

The accumulation of many threats increases the overall risk.

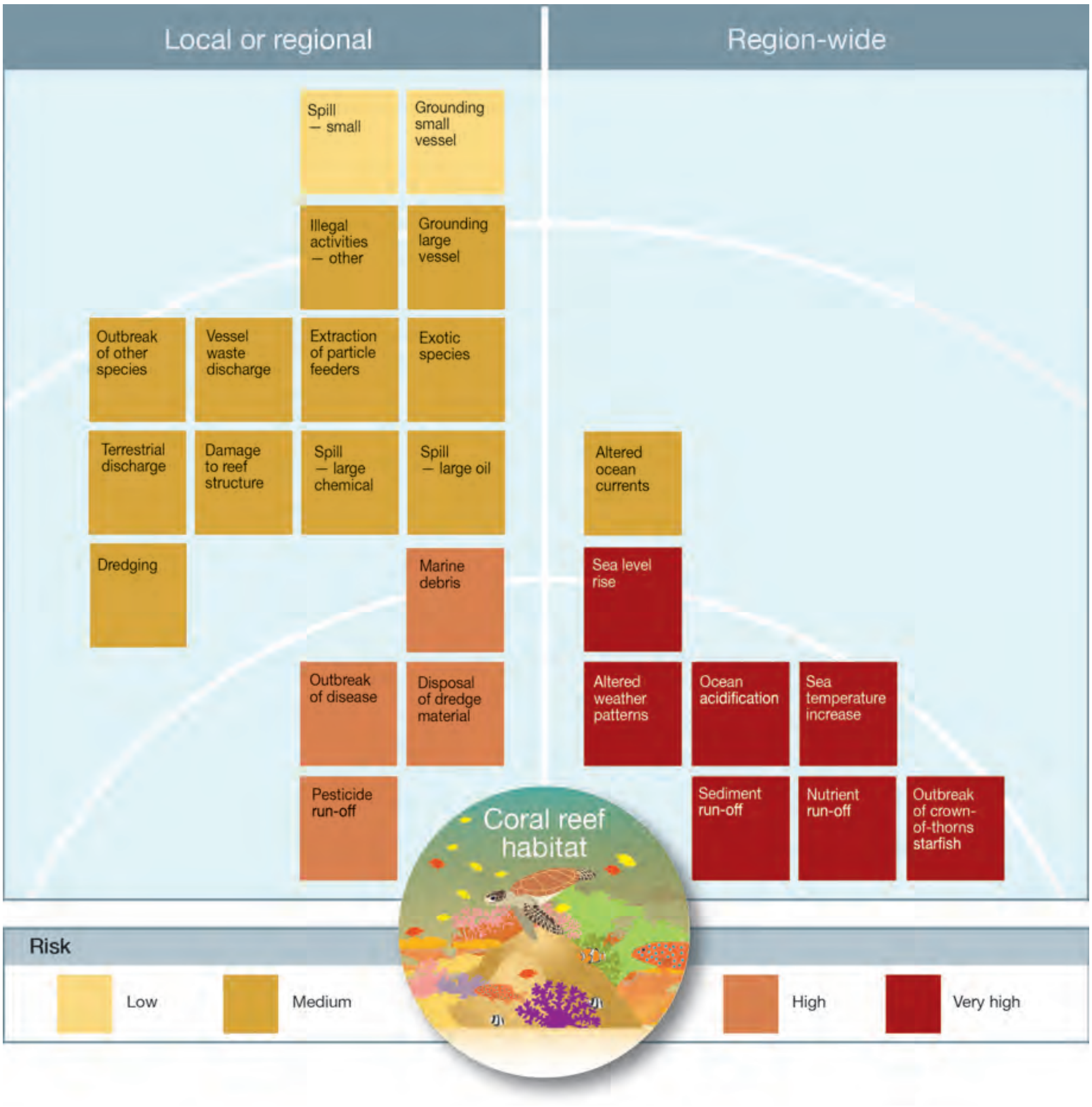


Figure 9.7 Cumulative effects on coral reef habitats
As noted in Chapter 2, the condition of coral reef habitats is declining. The major causes of this decline (land-based run-off, outbreaks of crown-of-thorns starfish, coral bleaching and cyclones) have been identified at a broad Region-wide scale.[14,20,21] *However, when considered at the local scale, there are many additional threats that directly affect coral reef habitats. Like any of the Region's ecosystem and heritage values, consideration of all threats affecting coral reefs, regardless of the level of risk or the scale at which the threat operates, is essential to improving the habitat's resilience. This is particularly important given the declining trends for coral reef habitats in much of the Region and the central role they play in the Reef ecosystem and its outstanding universal value as a world heritage property.*

9.4 Assessment summary — Risks to the Region's values

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. Section 116A(2)(b) of the Regulations requires '*an assessment of the risks to the heritage values…*' of the Great Barrier Reef Region.

Separate assessments are provided for the Region's ecosystem and its heritage values, based on their current state and trends, the factors influencing them, the effectiveness of protection and management measures and an understanding of their overall resilience.

9.4.1 Risks to the ecosystem

Outlook Report 2009: Assessment summary
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.

2009 Grade	Current summary and assessment components	Assessment grade and trend				Confidence	
		Low risk	Medium risk	High risk	Very high risk	Grade	Trends
🟧	**Overall risk to ecosystem:** The Region's ecosystem continues to be at serious risk and the threats likely to affect it in the future are increasing and compounding. The most serious risks arise from climate change, land-based run-off, coastal development and some aspects of direct use (particularly fishing). Other threats relating to direct use are more effectively managed and of less overall risk to the Reef.			🟧 ↑ ↑			
🟥	**Climate change:** The threats of sea temperature increase, altered weather patterns, ocean acidification and sea level rise continue to be some of the most serious risks to the Reef ecosystem. The risk is likely to increase in the future due to emissions trajectories and unavoidable future change locked in by past emissions.				🟥 ↑ ↑	●	●
🟧	**Coastal development:** Clearing and modifying coastal habitats and artificial barriers to flow are serious risks to the Reef. Increased coastal development increases the likelihood of these threats. Direct use causes demand for some aspects of coastal development.			🟧 ↑ ↑		●	●
🟧	**Land-based run-off:** While loads of nutrients and sediments are being reduced, understanding of the detrimental effects on the ecosystem has improved. The continued inputs and the lag between reduced inputs and improved ecosystem condition mean that nutrients, sediments and pesticides in land-based run-off will continue to be a serious long-term risk to the ecosystem. Marine debris from all sources will also remain a high risk.			🟧 ↔ ↓		●	●
🟨 Non-extractive 🟧 Extractive	**Direct use:** Many threats from direct use are localised and of low to medium risk. However, some significant risks remain. Illegal fishing and collecting, extraction of predators, extraction from unidentified or unprotected spawning aggregations, incidental catch of species of conservation concern and effects on discarded catch are rated as high or very high risk. Although overall risk from ports is assessed as medium, increases in port-related activity combined with future projections and a continued incomplete understanding of the potential ecosystem effects have increased the assessed risk for disposal and resuspension of dredge material.		🟨 ↑			●	●

Grading statements

Low risk	**Medium risk**	**High risk**	**Very high 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.	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.	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.	Given current management arrangements, there are likely or almost certain threats that are predicted to have catastrophic consequences on the Region's ecosystem.

Trend since 2009

↑ Increased
↔ Stable
↓ Decreased
– No consistent trend

No symbol: There were two assessments for **Direct use** in 2009; no trend provided.

Future trend

↑ Increasing
↔ Stable
↓ Decreasing
– No consistent trend

Confidence

● Adequate high-quality evidence and high level of consensus
◐ Limited evidence or limited consensus
○ Inferred, very limited evidence

9.4.2 Risks to heritage values

Outlook Report 2009: Not assessed

2009 Grade	Current summary and assessment components	Assessment grade and trend				Confidence	
		Low risk	Medium risk	High risk	Very high risk	Grade	Trend
Not assessed	**Overall risk to heritage values:** The close connections between the Region's ecosystem and many of its heritage values mean that the projected risk of almost all threats is the same in both assessments. As a result, the most serious risks to the Region's heritage values are similarly climate change, land-based run-off, coastal development and some aspects of direct use.			🟧 ↑			
Not assessed	**Climate change:** The threats to the ecosystem associated with climate change flow on to present a serious risk to heritage values, particularly the property's outstanding universal value. Some shallow-water Indigenous and historic heritage sites are also at risk.				🟥 ↑	◐	◐
Not assessed	**Coastal development:** Legacy and contemporary changes in terrestrial habitats as a result of coastal development will continue to affect the outstanding universal value in forthcoming decades and the integrity of the world heritage property. Natural scenic values may also be further diminished, along with Indigenous heritage values.			🟧 ↑		◐	◐
Not assessed	**Land-based run-off:** The widespread effects of pollutants (including marine debris) in land-based run-off will continue to diminish many attributes of outstanding universal value, especially in inshore areas. Resulting declines in ecosystem values will affect related Indigenous heritage values and the overall aesthetic value of wide areas of the Region.			🟧 ↓		◐	◐
Not assessed	**Direct use:** The risks that direct use presents to the ecosystem are reflected in its risk to heritage values. In addition, if heritage values are not properly identified and considered, there is a risk that activities could damage (potentially irreversibly) heritage sites, reduce natural beauty, and affect the ability of Traditional Owners to undertake cultural practices. Of particular concern are effects on Indigenous heritage values from incompatible uses.		🟨 ↑			◐	◐

Grading statements				Trend since 2009
🟨 **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 Region's heritage values. There may be minor or moderate consequences for heritage values 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 heritage values and none will have catastrophic consequences. Some unlikely threats may have major consequences for the Region's heritage values.	🟧 **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 heritage values.	🟥 **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 heritage values.	New assessment for this report; no trend provided

Future trend

- ↑ Increasing
- ↔ Stable
- ↓ Decreasing
- − No consistent trend

Confidence

- ● Adequate high-quality evidence and high level of consensus
- ◐ Limited evidence or limited consensus
- ○ Inferred, very limited evidence

9.4.3 Overall summary of risks to the Region's values

Based on current management, the Great Barrier Reef Region's ecosystem and heritage values face a range of increasing risks into the future. The close connections between ecosystem components and heritage values mean the projected risk for many impacts is equivalent for both sets of values. The identified threats to the Region's values arise from a number of sources and are highly variable in both scale and timeframe. A lack of understanding of the extent and location of many heritage values (for example wrecks and archaeological sites) means that the risks to them may be underestimated.

Views expressed by community members about the greatest risks to the Region are similar to the outcomes of the structured risk assessment, with climate change, land-based run-off, shipping, port development, fishing, marine debris and pollution common responses. This represents an increase in community concern about some threats since Outlook Report 2009 (for example marine debris, shipping and port development).

The greatest long-term threats facing the Great Barrier Reef ecosystem are from climate change. For all the Region's values, threats associated with rising levels of greenhouse gases in the atmosphere such as ocean acidification, increased sea temperatures and rising sea level are likely to become more severe into the future. Therefore, these threats pose an increasing risk to the Region's values. Their impact will be compounded by each other and by other existing regional and local threats.

Generally, increases in assessed risk since the Outlook Report 2009 have resulted from an increased understanding of the threat, its distribution and the likely severity of its consequences. Only the risk of pesticides from land-based run-off has decreased based on new information, from very high to high.

Management arrangements are reducing some lower risk threats; examples include the continued strong management of direct uses such as commercial marine tourism and improvements in the management of shipping activities in the Region. The planning, inputs and processes associated with managing land-based run-off have improved and over time risk is expected to decrease somewhat as a result.

Other activities, in particular coastal development and the remaining impacts of fishing, are still assessed as high risk and desired management outcomes are not being achieved.

The most serious threats are from climate change, land-based run-off, coastal development and some aspects of direct use such as illegal fishing and poaching and the incidental take of species of conservation concern. These threats have the potential to work in combination to weaken the resilience of the Great Barrier Reef ecosystem and therefore its ability to recover from serious disturbances (such as major coral bleaching events) that will become more frequent in the future. An increased understanding of the cumulative effects of threats has highlighted the need for a management approach that takes into account all threats affecting an area and for a combination of Reef-wide, regional and local solutions.

While climate change will affect all parts of the Great Barrier Reef, the compounding effects of other threats means that inshore environments next to developed areas are most at risk.

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Long-term outlook

CHAPTER 10

'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*

'an assessment of the long-term outlook for the heritage values…' of the Great Barrier Reef Region,
Section 116A(2)(f) *of the Great Barrier Reef Marine Park Regulations 1983*

2014 Summary of assessment

Outlook for the ecosystem	The Great Barrier Reef ecosystem is under pressure. Cumulative effects are diminishing the ecosystem's ability to recover from disturbances. Some threats are increasing, driven mainly by climate change, economic growth and population growth. The emerging success of some initiatives (such as improving land-based run-off) means some threats may be reduced in the future. However, there are significant lags from when actions are taken to improvements being evident in the ecosystem. More than ever, a focus on building resilience by reducing all threats is important in protecting the Region's ecosystem and its Outstanding Universal Value into the future.	🟩 ↓ ↓ Poor, Deteriorated, Deteriorating
Outlook for heritage values	The close connection between the Region's ecosystem and its heritage values means that many are deteriorating as ecosystem condition declines, for example Indigenous heritage values. Similarly, attributes that contribute to the Outstanding Universal Value of the Great Barrier Reef are under pressure from a range of threats. The Region's social significance, built around a history of personal experiences, will continue to shift as use changes. Underwater aesthetic values will likely continue to decline. The outlook for historic heritage values will be influenced by how well sites are recorded and maintained. Increasing recognition of the Region's heritage values improves their likely outlook.	🟦 ↓ Good, Deteriorating

Full assessment summary: see Section 10.5

< Photograph © Chris Jones

Long-term outlook

10.1 Background

> **Outlook Report 2009:** Overall summary of long-term outlook for the ecosystem
>
> 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.

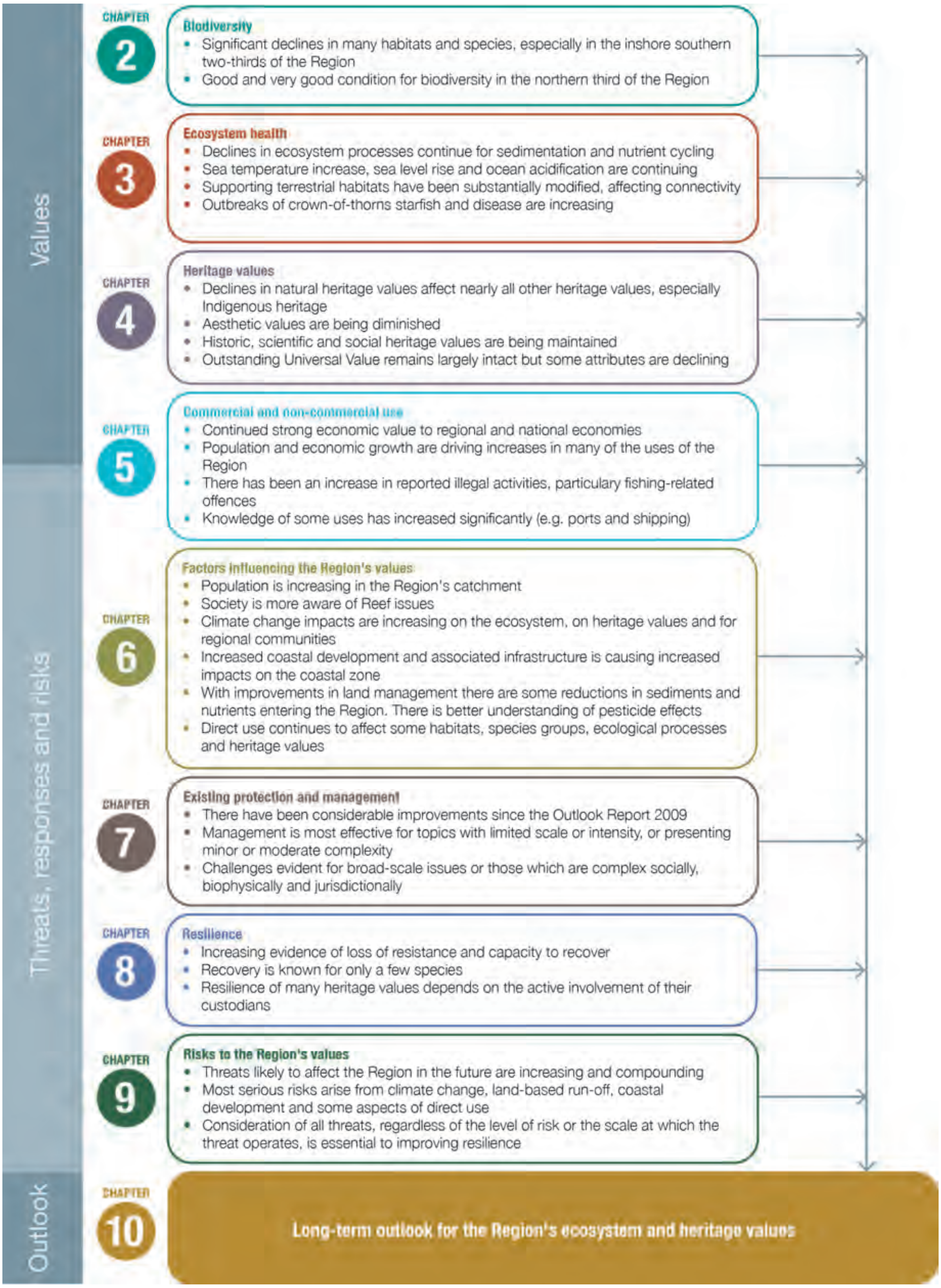
The preceding chapters have assessed the current condition and trend of the ecological, economic, social and heritage values of the Great Barrier Reef Region (the Region) (Chapters 2, 3, 4 and 5), the factors affecting those values (Chapter 6), the effectiveness of protection and management measures (Chapter 7), the resultant resilience of the Region's ecosystem and its heritage values (Chapter 8), and finally, the risks the ecosystem and heritage values are facing (Chapter 9). The outcomes of these assessments (Figure 10.1) — combined with consideration of the knowledge available for management, likely future trends and current and future management initiatives — can be used to build an updated picture of the predicted long–term outlook for the Region.

The future outlook is based on the report's assessments and future initiatives.

The Region's ecosystem and its heritage values are many, diverse and inter-related as well as being socially, biophysically and jurisdictionally complex. This complicates assessing their likely long-term future as a multitude of influencing factors and current and future management initiatives must be considered.

10.2 Knowledge for management

A comprehensive and up-to-date understanding of the Region's values, the processes supporting them and the impacts affecting them is fundamental to their management. Knowledge and understanding is improved through the activities of a wide range of research providers such as the Australian Institute of Marine Science, CSIRO, government agencies and universities, as well as by commercial companies and consultants, stakeholders, Traditional Owners and community members.



Biodiversity
- Significant declines in many habitats and species, especially in the inshore southern two-thirds of the Region
- Good and very good condition for biodiversity in the northern third of the Region

Ecosystem health
- Declines in ecosystem processes continue for sedimentation and nutrient cycling
- Sea temperature increase, sea level rise and ocean acidification are continuing
- Supporting terrestrial habitats have been substantially modified, affecting connectivity
- Outbreaks of crown-of-thorns starfish and disease are increasing

Heritage values
- Declines in natural heritage values affect nearly all other heritage values, especially Indigenous heritage
- Aesthetic values are being diminished
- Historic, scientific and social heritage values are being maintained
- Outstanding Universal Value remains largely intact but some attributes are declining

Commercial and non-commercial use
- Continued strong economic value to regional and national economies
- Population and economic growth are driving increases in many of the uses of the Region
- There has been an increase in reported illegal activities, particulary fishing-related offences
- Knowledge of some uses has increased significantly (e.g. ports and shipping)

Factors influencing the Region's values
- Population is increasing in the Region's catchment
- Society is more aware of Reef issues
- Climate change impacts are increasing on the ecosystem, on heritage values and for regional communities
- Increased coastal development and associated infrastructure is causing increased impacts on the coastal zone
- With improvements in land management there are some reductions in sediments and nutrients entering the Region. There is better understanding of pesticide effects
- Direct use continues to affect some habitats, species groups, ecological processes and heritage values

Existing protection and management
- There have been considerable improvements since the Outlook Report 2009
- Management is most effective for topics with limited scale or intensity, or presenting minor or moderate complexity
- Challenges evident for broad-scale issues or those which are complex socially, biophysically and jurisdictionally

Resilience
- Increasing evidence of loss of resistance and capacity to recover
- Recovery is known for only a few species
- Resilience of many heritage values depends on the active involvement of their custodians

Risks to the Region's values
- Threats likely to affect the Region in the future are increasing and compounding
- Most serious risks arise from climate change, land-based run-off, coastal development and some aspects of direct use
- Consideration of all threats, regardless of the level of risk or the scale at which the threat operates, is essential to improving resilience

Long-term outlook for the Region's ecosystem and heritage values

Figure 10.1 Building a picture of the long-term outlook for the Region's ecosystem and heritage values
Combined, the conclusions from the preceding chapters build an up-to-date picture of the predicted long–term outlook for the Region's ecosystem and heritage values.

A continually improving understanding of the Region's values and the threats to them will play a major role in securing their long-term future. The amount of research conducted in the Region and the focus of that research is determined by a number of variables including: the priorities of funding bodies; the priorities of research users such as government agencies; and the research interests and capacities of scientists in universities and research institutions.

Following the Outlook Report 2009, there was a stocktake of the scientific and other knowledge available about the Region, with gaps identified. The subsequent report, *Scientific Information Needs for the Management of the Great Barrier Reef Marine Park 2009–2014*[1], guided investment in research to underpin management.

Continually improving understanding is a key to securing the Reef's future.

10.2.1 Improved understanding

Since 2009, understanding of recent trends in the condition of some ecosystem components has improved. For example, comprehensive data about key components relating to water quality in the Region are now collected and synthesised in annual report cards. There has also been pivotal analysis of the long-term dataset on coral reefs that has highlighted ongoing and significant declines. In addition, recent research has revealed what coral reefs were like long before current methods of scientific measurement. This is critical to understanding the baseline condition of reefs in the Region.

The importance of good **connectivity**, both within the Region and with its supporting terrestrial habitats, is increasingly recognised. The Paddock to Reef program continues to improve knowledge of how activities in the catchment affect the Reef ecosystem. There is also better understanding of connectivity within the ecosystem such as between fished and unfished reefs. Integrated marine observing infrastructure is allowing more robust and accurate hydrodynamic and other models to be developed for the Region.

Understanding of the impacts on the Region's ecosystem caused by a loss of connectivity and ecosystem services as a result of clearing and modifying coastal habitats has improved considerably. As has understanding of the actions needed to protect and restore such habitats.

There has been increased recognition of the key factors relevant to the overall future of the Region's ecosystem and its heritage values. As outlined in previous chapters, drivers, activities, past and current impacts and future risks do not operate independently, but are intertwined in a complex web causing cumulative effects. Recently, techniques for better conceptualising cumulative impacts within the context of the Region and its catchment have started to emerge.[2,3] 'SeaSim', an ocean simulation facility at the Australian Institute of Marine Science which became operational in 2013, will enable an improved understanding of cumulative impacts.

Economic and population growth, technological developments, and societal attitudes are more explicitly recognised in this report (see Chapter 6) as **key drivers** for the Region's values than in the Outlook Report 2009. Improved understanding of their trends provides context for proactive and appropriate management of the values and the influences on them, in a way that takes into account likely future changes. These social and economic drivers are being monitored through a recently established Social and Economic Long-term Monitoring Program.

Although **heritage values** were implicitly considered within some aspects of the Outlook Report 2009, a far more formal and comprehensive approach has now been established. The Region's heritage values are now better defined, including through specific studies to scope aesthetic[4] and geomorphological[5] attributes, and there is greater recognition of the direct connections between heritage values and the Reef ecosystem.

10.2.2 Remaining information gaps

Notwithstanding continuing improvements in knowledge, filling a number of key remaining gaps would greatly assist understanding of the Region and improve management.

The importance of developing ways to understand and respond to the effects of **cumulative impacts** on the Region's values is paramount. The need to develop decision-support tools and methods for considering multiple direct, indirect and consequential impacts is now recognised as a requirement for management into the future.

Understanding and responding to cumulative impacts is paramount.

There is a need to develop strategies and technologies for the **restoration of degraded habitats** and to improve the health and resilience of the ecosystem.

Information from research and monitoring will be critical to the development of **thresholds** for ecosystem health and **targets** for management actions, and to track the effectiveness of such actions.

Research will also be needed to conceptualise and, in some cases, **model** how a system works and how the elements interact and respond to changing pressures.

Traditional ecological knowledge and local community knowledge shared by Traditional Owners, stakeholders and members of the community will play a central role in better **understanding heritage values** and informing adaptive management and decision making. Furthermore, integrating traditional and

Improved modelling of the ecosystem will inform management actions © Matt Curnock

community knowledge with scientific knowledge can extend the time perspective of scientific knowledge and highlight potential subject areas for future studies.[6]

With regard to applying knowledge to management, key areas of focus include integrating knowledge, monitoring and reporting into adaptive management; improving alignment and coordination of research priorities; increasing emphasis on the use of modelling approaches; improving spatial mapping capabilities; supporting long-term monitoring programs; and standardising data collection and facilitating sharing.

10.3 Likely future trends

Trends in factors influencing the long-term outlook for the Region's ecosystem and heritage values operate at large (globally for climate change) and local geographic scales and have varying social, biophysical and jurisdictional complexities. The future of the Region's values will be largely determined by the cumulative effects of these factors, the effectiveness of management to increase resilience in the system and an ability to harness and integrate new information to inform future management responses.

10.3.1 Influencing factors

Trends in some key external factors will combine to affect the Region's ecosystem and heritage values.

Drivers Economic growth is projected to continue in Queensland with a large proportion of this growth occurring adjacent to the Region. Population in the Great Barrier Reef catchment is expected to continue to grow at rates well above the national average for the foreseeable future. Some of this growth is a result of economic growth, especially in the resources sector. Both these drivers change land-use patterns in the catchment, including expanding the urban footprint to accommodate an increasing number of residents and increasing demand for infrastructure to support the resources industries. They also drive increases in use of the Region, for example shipping and recreational activities.

Technological advances will continue and can provide positive outcomes for the Region and for management of the catchment (for example better navigational safety for ships and reduced fertiliser use). They can also increase some threats to the Region's ecosystem and its heritage values (for example depth sounders and global positioning systems improving fishers' ability to find, relocate and catch fish). Societal attitudes about the Great Barrier Reef will continue to be shaped by its iconic status as well as information about its condition and likely future. Such attitudes affect how people think about the Reef and the way they use it. This can enhance engagement in stewardship programs and uptake of best practice actions.

Climate change As well as indirectly driving change in factors that influence the Reef, climate change will directly influence the Region and continue to have far-reaching consequences. Future predictions indicate sea level rises and temperature increases will continue, ocean pH will gradually decline and weather will be more severe. These changes will have dramatic effects on the Region's ecosystem and heritage values and the Reef-dependent industries that rely on them (for example commercial marine tourism and commercial fishing).

Coastal development Changes in land use over the last two centuries have determined the current extent and condition of natural ecosystems in the catchment. Continued modifications of terrestrial habitats that support the Great Barrier Reef are likely based on forecast changes in some agricultural sectors and projected increases in urban and industrial development, driven partly by economic growth. This in turn will drive increases in direct use of the Region.

Land-based run-off Although agricultural practices in the Great Barrier Reef catchment are improving, there is likely to be a significant lag time before water quality improvements in the Region are measured.

Sediments, nutrients and pesticides will continue affecting the ecosystem and heritage values for decades to come.

There is increasing evidence that current trends for crown-of-thorns starfish outbreaks are likely to continue, contributing further to coral reef mortality, until such time that the Region's water quality has improved.

Marine debris continues to enter the Region and will persist for decades. It will continue to affect the Region's ecosystem and heritage values, especially species of conservation concern and aesthetic values.

Direct use The Region is expected to continue to be a significant contributor to regional and national economies through commercial and non-commercial uses. Past declines in tourism visitor numbers are reversing, but will continue to depend on global economic factors (such as monetary exchange rates).

The Great Barrier Reef continues to be valued well beyond its local communities, with strong national and international interest. It will continue to be of major importance to its Traditional Owners and the maintenance of their cultural values. People that visit the Region are expected to continue to enjoy their experiences.

Impacts from direct use of the Region are many and will continue to present varying degrees of risk to the ecosystem and heritage values. Continuation of current management arrangements should effectively avoid many impacts, for example those related to commercial marine tourism, defence activities and shipping. Improvements in Traditional Owner community compliance programs related to reporting and detection of illegal activities are expected to continue for at least the next few years.

Many potential impacts of direct use are avoided under current management; some key risks remain.

Without effective mitigation devices and management arrangements, the death of incidentally caught species of conservation concern will almost certainly continue across all fisheries and the Queensland shark control program, with major consequences for their populations and Traditional Owner cultural values. Non-compliance with management arrangements, especially illegal fishing, is predicted to continue into the future, with the ongoing effect of compromising management outcomes for the Region's ecosystem and its heritage values. Predicted increases in use of the Region may increase the risk of associated threats, such as incompatible uses at popular sites.

10.3.2 Management effectiveness

Since 2009, effectiveness has been assessed as improving for two areas of management focus: land-based run-off and traditional use of marine resources. These results illustrate the importance of strategic planning, research to inform management and significant commitment of resources.

There continues to be particular management challenges in consistency across jurisdictions, and in understanding the values and better incorporating their consideration in decision making, although progress is being made.

The difficulties in achieving positive outcomes on the ground are likely to continue — given the complexity of many issues, the spatial and temporal scales of the threats to the Region's values and the diminishing resource base to implement actions. The lagging response in desired outcomes for the Region is largely a result of the time needed to effect change in the system.

10.3.3 Resilience

There is increasing evidence of ongoing loss of resistance and recovery capacity in the Region's ecosystem and heritage values, although the extent of loss varies considerably. As the effects of climate change worsen, it is likely that interactions between climate-related threats and other threats will have increasingly serious consequences. Given the only partial effectiveness of existing protection and management in addressing the most significant pressures on the ecosystem (principally arising from outside the Region), the loss of resilience is expected to continue. Maintaining the resilience of the Region's ecosystem and heritage values will require major increases in effort to reduce local and global threats and to build understanding of the values themselves.

The Reef's resilience is likely to decline further without major reductions in current threats.

10.3.4 Risks to the Region's values

The threats associated with the four factors influencing the Region's values will continue to act cumulatively, dominated by those that present the highest risk, but added to by those of medium and low risk. Their effects will be amplified if there continues to be a decline in the resilience of the Region's ecosystem.

Of the threats assessed, the risk of most has not changed since 2009. The assessed risk of nine threats has increased. This is largely as a result of increased understanding of the threats, their distribution and the likely severity of their consequences (see Chapter 9). Increased understanding of the effects and spatial extent of pesticides from land-based run-off has reduced its assessed risk — the only threat where the risk has decreased.

10.3.5 Prospects for the outstanding universal value of the Great Barrier Reef World Heritage Area

Future prospects for the Reef's Outstanding Universal Value depend on concerted global and local actions.

Although many of the attributes contributing to the Great Barrier Reef World Heritage Area's outstanding universal value remain in good or very good condition, the condition of many has declined since 1981.

Factors external to the area — climate change, land-based runoff and coastal development — are affecting the property's integrity. These are the most complex and wide-ranging of the threats assessed. They are combining with other threats within the property to increase the cumulative risk to its future.

Although management continues to be effective for many activities within and adjacent to the World Heritage Area, there remain difficulties in achieving positive outcomes on the ground.

That the Great Barrier Reef continues to be highly valued by the global, Australian and local communities provides evidence for societal support for the continued protection of its outstanding universal value.

Prospects for the future of the Great Barrier Reef's outstanding universal value depend on global action to address the causes of climate change, and on coordinated, targeted and dedicated long-term commitments to continue to address the risks within and adjacent to the property. There is evidence that when there are concerted efforts to address damaging practices, impacts can be halted and reversed.

There is no short-term single action that will secure the outstanding universal value of the Great Barrier Reef. However, working at global, regional and local levels will be the best solution to preserving the world heritage area.

10.4 Current and future initiatives to improve resilience and protect values

The Outlook Report 2009 recognised that building on the existing management arrangements in the Region would help address the key threats to the Region and that these actions and the degree to which they were effectively implemented would strongly influence the resilience of the Reef ecosystem in the future.

10.4.1 Contributions to protection and management

In addition to a range of Australian and Queensland government agencies, there are many other partners that continue to make significant contributions to protecting and managing the Region.

Marine Park users are continuing to adopt **best practice standards** during their activities in the Region. For example, through the High Standard Tourism program and voluntary actions, tourism operators are incorporating best practices into their activities.

In addition, many stakeholders and members of the community continue to participate in research and monitoring programs such as the Eye on the Reef program including the Reef Health and Impact Surveys, Tourism Weekly monitoring, Sightings Network and Rapid Monitoring survey program. The scientific community actively contributes by undertaking research to address key issues facing the Region.

Many partners continue to contribute to protection and management.

A range of **stewardship** programs involve those who use and rely on the Region or its catchment for their recreation or business taking voluntary actions beyond what is required by law to ensure the environmental sustainability of the Region and to improve the economic sustainability of industries operating there. Activities include cleaning up marine debris, restoring habitats that support the Reef ecosystem, improving land management practices in the catchment, and undertaking targeted control of crown-of-thorns starfish.

Twelve Local Marine Advisory Committees, from Cooktown to Bundaberg and comprising 185 members across the range of industry and community interests, provide **advice to management agencies** on issues and policies relating to specific activities, conservation, environment, public information and public education concerning their local marine and coastal areas.

10.4.2 Future commitments

In assessing the long-term outlook for the Region's ecosystem and its heritage values, current management arrangements plus relevant management initiatives identified but not yet fully implemented (Figure 10.2) are considered. The future commitments of both the Australian and Queensland governments identified in the program reports of the strategic assessments[7,8] are part of these considerations. They recognise the need to implement a management framework that:

- establishes measurable ecosystem outcomes and is driven by specific measurable targets
- will either prevent or reduce cumulative impacts
- enables a net benefit approach to help achieve outcomes and targets, especially in areas requiring restoration
- is supported by a comprehensive integrated monitoring and reporting framework.

The reports recognise that, while avoiding, mitigating and offsetting impacts remain a very important focus of management efforts, these are not sufficient on their own because, in many areas, the system now needs policies of restoration, not simply prevention of damage. Additional interventions that deliver an overall positive effect (net benefit) are required to halt and reverse the decline in the Region's ecosystem health and ensure the long-term protection and restoration of its values. Using ecosystem outcomes and targets as a guide, initiatives are foreshadowed in:

- environmental regulation
- engagement
- knowledge, integration and innovation.

Environmental regulation Through management tools such as regulations, zoning plans, plans of management, permits and compliance, management agencies will continue to set and refine the environmental standards necessary to achieve the desired goals, outcomes and targets for the Region's values. The continued effectiveness of the zoning plans rely in part on the continued enforcement of zoning arrangements and ensuring Reef users are aware of the plans and their provisions.

Engagement Protection of the Great Barrier Reef requires local, national and international effort. A program of Reef Recovery — adopting regionalised and cooperative management approaches that support local communities and encourage cooperation between government agencies, the private sector and research institutions — will be developed to implement actions to protect and restore biodiversity hotspots and support sustainable use. Ongoing and collaborative working relationships will instil a sense of collective stewardship. This approach will provide a strong foundation for maintaining a balance between protecting the Region's values, managing competing demands and supporting sustainable use.

Knowledge, integration and innovation Accessing the best available science from a network of science providers, both nationally and internationally, as well as drawing on traditional ecological knowledge and information from the wider community is essential for effective management. Building on existing programs, such as long-term coral and fish monitoring undertaken by the Australian Institute of Marine Science and marine monitoring managed by the Great Barrier Reef Marine Park Authority, monitoring will continue to provide evidence of changes in the ecosystem as well as the effectiveness of management actions. Filling key information gaps through targeted research will be critical, and monitoring will be used to assess the success of management measures. Implementing a Reef-wide integrated monitoring and reporting program which directly links to an outcomes-based management framework will underpin an adaptive management approach. The framework will guide the establishment of a standardised and integrated ecological, social and economic monitoring program for the Great Barrier Reef.

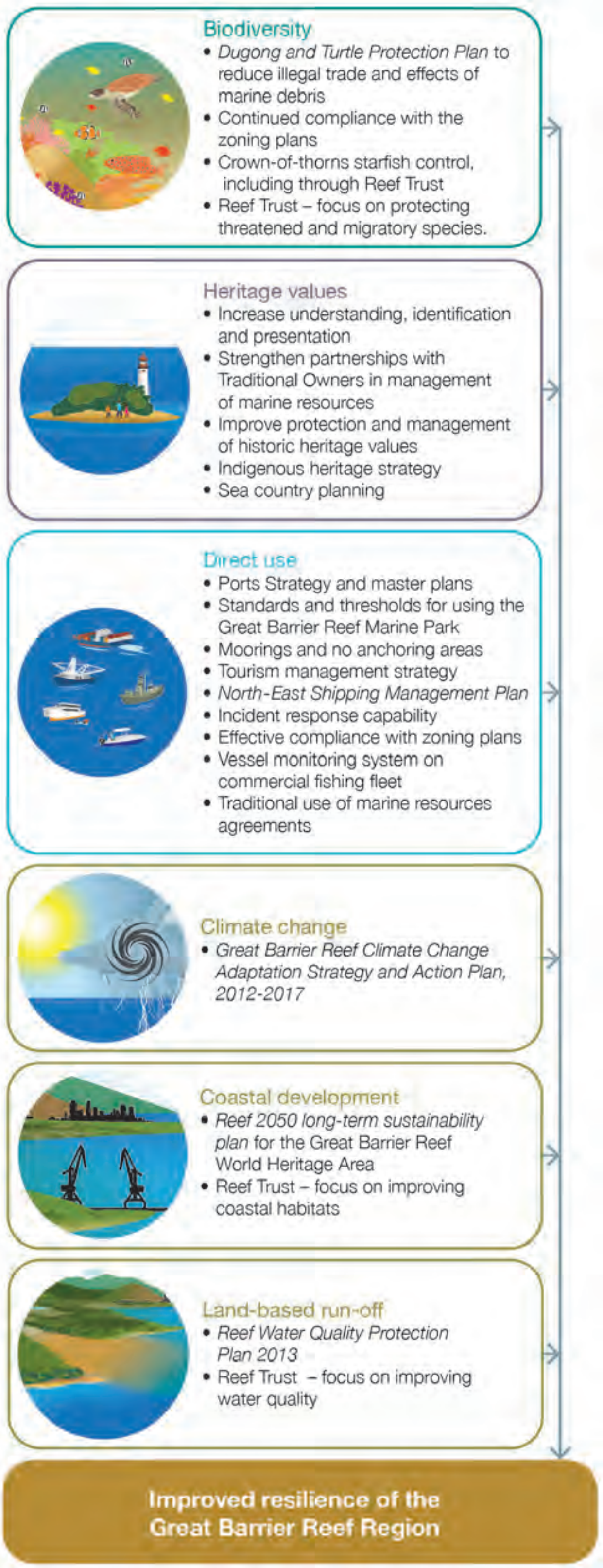


Figure 10.2 Current and future initiatives to improve the Region's resilience

10.5 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. Section 116A(2)(f) of the *Great Barrier Reef Marine Park Regulations 1983* requires '*an assessment of the long-term outlook for the heritage values*…' of the Great Barrier Reef Region.

10.5.1 Outlook for the Region's ecosystem

Outlook Report 2009: Assessment summary

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.

2009 Grade	Current summary	Assessment grade and trend				Confidence	
		Very good	Good	Poor	Very poor	Grade	Trends
🟩	**Outlook for the ecosystem:** The Great Barrier Reef ecosystem is under pressure. Cumulative effects are diminishing the ecosystem's ability to recover from disturbances. Some threats are increasing, driven mainly by climate change, economic growth and population growth. The emerging success of some initiatives (such as improving land-based run-off) means some threats may be reduced in the future. However, there are significant lags from when actions are taken to improvements being evident in the ecosystem. More than ever, a focus on building resilience by reducing all threats is important in protecting the Region's ecosystem and its outstanding universal value into the future.			🟩 ↓ ↓		●	◐

Grading statements

🟦 **Very good**	🟦 **Good**	🟩 **Poor**	🟩 **Very poor**
The values are likely to remain healthy and resilient for the foreseeable future with strong recovery at damaged locations. Additional management intervention is not required to maintain the values.	With only minor additional management intervention, the values are likely to remain generally healthy and resilient for the foreseeable future, with only some values showing signs of significant deterioration.	Without significant additional management intervention, some of the values will deteriorate in the next 25 years and only a few values are likely to be healthy and resilient in the longer term.	Without urgent and effective additional management intervention, the values are likely to deteriorate rapidly with the loss of most values in the longer term.

Trend since 2009	Future trend
↑ Improved	↑ Improving
↔ Stable	↔ Stable
↓ Deteriorated	↓ Deteriorating
− No consistent trend	− No consistent trend

Confidence

- ● Adequate high-quality evidence and high level of consensus
- ◐ Limited evidence or limited consensus
- ○ Inferred, very limited evidence

10.5.2 Outlook for the Region's heritage values

Outlook Report 2009: Not assessed

2009 Grade	Current summary	Assessment grade and trend				Confidence	
		Very good	Good	Poor	Very poor	Grade	Trend
Not assessed	**Outlook for heritage values:** The close connection between the Region's ecosystem and its heritage values means that many are deteriorating as ecosystem condition declines, for example Indigenous heritage values. Similarly, attributes that contribute to the outstanding universal value of the Great Barrier Reef are under pressure from a range of threats. The Region's social significance, built around a history of personal experiences, will continue to shift as use changes. Underwater aesthetic values will likely continue to decline. The outlook for historic heritage values will be influenced by how well sites are recorded and maintained. Increasing recognition of the Region's heritage values improves their likely outlook.		🟦 ↓			◐	◐

Grading statements

🟦 **Very good**	🟦 **Good**	🟩 **Poor**	🟩 **Very poor**
The values are likely to remain healthy and resilient for the foreseeable future with strong recovery at damaged locations. Additional management intervention is not required to maintain the values.	With only minor additional management intervention, the values are likely to remain resilient for the foreseeable future, with only some values showing signs of significant deterioration.	Without significant additional management intervention, some of the values will deteriorate in the next 25 years and only a few values are likely to be resilient in the longer term.	Without urgent and effective additional management intervention, the values are likely to deteriorate rapidly with the loss of most values in the longer term.

Trend since 2009	Future trend
New assessment for this report; no trend provided	↑ Improving ↔ Stable ↓ Deteriorating − No consistent trend

Confidence

- ● Adequate high-quality evidence and high level of consensus
- ◐ Limited evidence or limited consensus
- ○ Inferred, very limited evidence

10.5.3 Overall summary of long-term outlook

The Great Barrier Reef Region continues to face a combination of extremely serious challenges. The risks affecting the area's ecosystem and heritage values arise from a number of sources, both within and beyond its boundaries. They are acting in combination to affect, sometimes significantly, the long-term outlook for the Region and the prospects for the outstanding universal value of the Great Barrier Reef World Heritage Area.

Management arrangements, combined with improvements in land management practices and voluntary behaviour change as a result of stewardship initiatives, are beginning to effectively address some threats. However, more needs to be done at Reef-wide, regional and local scales.

Increased understanding of the ecosystem and heritage values, their trends and the factors affecting them will also be critical to improving the long-term outlook of the Region. Understanding the drivers of change is an essential step in providing a context for day-to-day decisions that influence the major trends in the system. There remain significant gaps, especially in understanding and modelling cumulative effects and in identifying thresholds for activities.

For some heritage values, their future largely depends on the condition of the natural ecosystem (for example Indigenous heritage, world heritage and national heritage values), while for others (for example historic heritage values) their future relies more on improving understanding and future management arrangements. Recognition of the importance of heritage values has increased in recent years, which provides a springboard for future management initiatives.

The cumulative effects of threats and the need to manage all of them to reduce stresses on the Region's values and to improve its resilience to future pressures are recognised. A business as usual approach to managing threats will not be enough. Achieving a healthy and resilient Great Barrier Reef into the future will require continued focus and even more effective action. The multitude of small decisions, such as anchoring at a popular snorkelling site, and the fewer, larger decisions, such as expanding a port channel, should be consistent with achieving the targets identified for the protection of the property's outstanding universal value. Without promptly reducing threats, there is a serious risk that resilience will not be improved and there will be irreversible declines in the Region's values.

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Appendices

Appendix 1 Statutory requirements for the Outlook Report

Extract from the *Great Barrier Reef Marine Park Act 1975*

Section 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.*

Extract from the *Great Barrier Reef Marine Park Regulations 1983*

Part 4AB — Reporting requirements

116A Great Barrier Reef Outlook Report

(1) For paragraph 54(3)(i) of the Act, an assessment of the heritage values of the Great Barrier Reef Region is prescribed as a matter that must be contained in the Great Barrier Reef Outlook Report.

(2) An *assessment of the heritage values*, of the Great Barrier Reef Region, includes the following:

- (a) an assessment of the current heritage values of the region;
- (b) an assessment of the risks to the heritage values of the region;
- (c) an assessment of the current resilience of the heritage values of the region;
- (d) an assessment of the existing measures to protect and manage the heritage values of the region;
- (e) an assessment of the factors influencing the current and projected future heritage values of the region;
- (f) an assessment of the long-term outlook for the heritage values of the region.

(3) In this regulation:

heritage values, of the Great Barrier Reef Region, include the following values for the region:

- (a) the Commonwealth Heritage values;
- (b) the heritage values;
- (c) the indigenous heritage values;
- (d) the National Heritage values;
- (e) the world heritage values.

Appendix 2 Key changes since the Outlook Report 2009

Chapter 1 — About this report

- *The Great Barrier Reef* chapter replaced with a chapter about the report, including an infographic on the Great Barrier Reef
- Assessment approach includes analysis of trend
- Assessment approach includes confidence ratings for grade and trend

Chapter 2 — Biodiversity

- *Shorebirds* added as an assessment component in the assessment of species and populations of species

Chapter 3 — Ecosystem health

- *Ocean currents* abbreviated to *Currents*
- *Recruitment* added as an assessment component in the assessment of ecological processes
- *Terrestrial habitats that support the Great Barrier Reef* added as a new assessment criterion
- Consideration of pesticide accumulation moved to Chapter 6

Chapter 4 — Heritage values

- New chapter added, focused on condition of heritage values

Chapter 5 — Commercial and non-commercial use

- *Ports and shipping* separated into two uses

Chapter 6 — Factors influencing the Region's values

- A section on *Drivers* added
- *Impacts on heritage values* added as a new assessment criterion

Chapter 7 — Existing protection and management

- *Ports and shipping* separated into two management topics
- *Community benefits* added as a management topic
- Section on the three broad management approaches (environmental regulation, engagement and knowledge, innovation and integration) added

Chapter 8 — Resilience

- Section on *Resilience of heritage values* added
- *Improving heritage resilience* added as a new assessment criterion

Chapter 9 — Risks to the Region's values

- *Risks to heritage values* added as a new assessment criterion
- List of threats revised, including the addition of *Incompatible uses* in relation to heritage values
- *Direct use* presented as a single assessment component, rather than divided into extractive and non-extractive use

Chapter 10 — Long-term outlook

- *Long-term outlook for the Region's heritage values* added as a new assessment criterion

Appendices

- Addition of appendices containing key changes since the last Outlook Report; attributes that contribute to the Region's outstanding universal value; indicators for management effectiveness; and risk assessments for threats to the ecosystem and heritage values

Appendix 3 Attributes that contribute to the outstanding universal value of the Great Barrier Reef

Given the broad scope of the criteria under which the Great Barrier Reef was listed as a world heritage property, almost all attributes of the ecosystem contribute to its outstanding universal value.

The *Statement of the outstanding universal value of the Great Barrier Reef World Heritage Area (2012)* is the official statement adopted by the World Heritage Committee outlining how the property met the criteria for outstanding universal value at the time of listing. The following excerpts of the statement indicate the attributes considered to contribute to the property's outstanding universal value.

Natural beauty and natural phenomena (Criterion (vii), previously (iii))

- Superlative natural beauty above and below the water
- Some of the most spectacular scenery on Earth
- One of a few living structures visible from space
- A complex string of reefal structures along Australia's north-east coast
- Unparalleled aerial panorama of seascapes comprising diverse shapes and sizes
- Whitsunday Islands provide a magnificent vista of green vegetated islands and white sandy beaches spread over azure waters
- Vast mangrove forests in Hinchinbrook Channel, or the rugged vegetated mountains and lush rainforest gullies
- On many of the cays there are spectacular and globally important breeding colonies of seabirds and marine turtles
- Raine Island is the world's largest green turtle breeding area
- Beneath the ocean surface, there is an abundance and diversity of shapes, sizes and colours… Spectacular coral assemblages of hard and soft corals
- Thousands of species of reef fish provide a myriad of brilliant colours, shapes and sizes
- The internationally renowned Cod Hole is one of many significant tourist attractions
- Superlative natural phenomena include the annual coral spawning, migrating whales, nesting turtles, and significant spawning aggregations of many fish species

Major stages of the Earth's evolutionary history (Criterion (viii), previously (i))

- Globally outstanding example of an ecosystem that has evolved over millennia
- Area has been exposed and flooded by at least four glacial and interglacial cycles, and over the past 18,000 years reefs have grown on the continental shelf
- Today, the Great Barrier Reef forms the world's largest coral reef ecosystem… Including examples of all stages of reef development
- Processes of geological and geomorphological evolution are well represented, linking continental islands, coral cays and reefs
- The varied seascapes and landscapes that occur today have been moulded by changing climates and sea levels, and the erosive power of wind and water, over long time periods
- One-third of the Great Barrier Reef lies beyond the seaward edge of the shallower reefs (and) comprises continental slope and deep oceanic waters and abyssal plains

Ecological and biological processes (Criterion (ix), previously (ii))

- Significant diversity of reef and island morphologies reflects ongoing geomorphic, oceanographic and environmental processes
- Complex cross-shelf, longshore and vertical connectivity is influenced by dynamic oceanic currents
- Ongoing ecological processes such as upwellings, larval dispersal and migration
- Ongoing erosion and accretion of coral reefs, sand banks and coral cays combine with similar processes along the coast and around continental islands
- Extensive beds of *Halimeda* algae represent active calcification and accretion over thousands of years
- Biologically the unique diversity of the Great Barrier Reef reflects the maturity of an ecosystem that has evolved over millennia; evidence exists for the evolution of hard corals and other fauna
- Vegetation on the cays and continental islands exemplifies the important role of birds....in seed dispersal and plant colonisation
- Human interaction with the natural environment is illustrated by strong ongoing links between Aboriginal and Torres Strait Islanders and their sea country, and includes numerous shell deposits (middens) and fish traps, plus the application of story places and marine totems

Habitats for conservation of biodiversity (Criterion (x), previously (iv))

- One of the richest and most complex natural ecosystems on Earth, and one of the most significant for biodiversity conservation
- Tens of thousands of marine and terrestrial species, many of which are of global conservation significance
- The world's most complex expanse of coral reefs... Contain some 400 species of corals in 60 genera
- Large ecologically important interreefal areas. The shallower marine areas support half the world's diversity of mangroves
- Large ecologically important interreefal areas. The shallower marine areas support … many seagrass species
- Waters also provide major feeding grounds for one of the world's largest populations of the threatened dugong
- At least 30 species of whales and dolphins occur here
- A significant area for humpback whale calving
- Six of the world's seven species of marine turtle occur in the Great Barrier Reef. As well as the world's largest green turtle breeding site at Raine Island, the Great Barrier Reef also includes many regionally important marine turtle rookeries
- Some 242 species of birds have been recorded in the Great Barrier Reef. Twenty-two seabird species breed on cays and some continental islands, and some of these breeding sites are globally significant
- The continental islands support thousands of plant species, while the coral cays also have their own distinct flora and fauna

Appendix 4 Indicators used to assess management effectiveness

To determine the effectiveness of management for each management topic, 49 indicators were considered across the six management elements.

Understanding of context

- The values of the Great Barrier Reef relevant to managing the topic are understood by managers
- The current condition and trend of values relevant to managing the topic are known by managers
- Impacts (direct, indirect and cumulative) relevant to managing the topic are understood by managers
- The broader (national and international) level influences relevant to managing the topic are understood by managers
- The stakeholders relevant to managing 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 factors influencing the Great Barrier Reef Region's values
- Actions for implementation regarding management of the topic are clearly identified within the plan
- Clear, measurable and appropriate objectives for management of the topic have been documented
- There are plans and systems in place to ensure appropriate and adequate monitoring information is gathered in relation to the topic
- The 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 topic
- Plans relevant to the topic provide certainty regarding where uses may occur, the type of activities allowed, conditions under which activities may proceed and circumstances where impacts are likely to be acceptable

Financial, staffing and information inputs

- Financial resources are adequate and prioritised to meet management objectives to address the topic
- Human resources within the managing organisations are adequate to meet specific management objectives to address the topic
- The right skill sets and expertise are currently available to the managing organisations to address the topic
- The necessary biophysical information is currently available to address the topic
- The necessary socioeconomic information is currently available to address the topic
- The necessary Indigenous heritage information is currently available to address the topic
- The necessary historic heritage information is currently available to address the topic
- There are additional sources of non-government input (for example volunteers) contributing to address the topic

Management systems and processes

- The main stakeholders and/or industry(ies) are effectively engaged in the ongoing management of the topic
- The local community is effectively engaged in the ongoing management of the topic

- There is a sound governance system in place to address management of the topic
- There is effective performance monitoring, including regular assessment of appropriateness and effectiveness of tools, to gauge progress towards the objective(s) for management of the topic
- Appropriate training is available to the managing agencies to address management of the topic
- Management of the topic is consistently implemented across the relevant jurisdictions
- There are effective processes applied to resolve differing views/conflicts regarding management of the topic
- Impacts (direct, indirect and cumulative) of activities associated with the topic are appropriately considered
- The best available biophysical research and/or monitoring information is applied appropriately to make relevant management decisions regarding the topic
- The best available socioeconomic research and/or monitoring information is applied appropriately to make relevant management decisions regarding the topic
- The best available Indigenous heritage information is applied appropriately to make relevant management decisions regarding the topic
- The best available historic heritage information is applied appropriately to make relevant management decisions regarding the topic
- Relevant standards are identified and being met regarding management of the topic
- Targets have been established to benchmark management performance for the topic

Delivery of outputs

- To date, the actual management program (or activities) have progressed in accordance with the planned work program for the topic
- Implementation of management documents and/or programs relevant to the topic have progressed in accordance with timeframes specified in those documents
- The results have achieved their stated management objectives for the topic
- To date, products or services have been produced in accordance with the stated management objectives for the topic
- Effective knowledge management systems regarding the topic are in place within agencies
- Effective systems are in place to share knowledge on the topic with the community

Achievement of outcomes

- The relevant managing agencies are to date effectively addressing the topic and moving towards the attainment of the desired outcomes
- The outputs relating to management of the topic are on track to ensure the values of the Great Barrier Reef are protected
- The outputs for management of 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 is demonstrably socially sustainable
- The relevant managing agencies have developed effective partnerships with local communities and/or stakeholders to address the topic

Appendix 5 Threats to the Region's values

The set of current and likely threats to the Great Barrier Reef Region's ecosystem and heritage values considered in the risk assessment (Chapter 9) was developed from the evidence presented in Chapters 5 and 6 of this report, taking into account input from the Great Barrier Reef Marine Park Authority's Local Marine Advisory Committees, Reef Guardian councils, teachers from Reef Guardian schools and Reef scientists, as well as the outcomes of various community surveys. The 41 threats considered are listed in the table below. The table also provides a comparison with those assessed in the Outlook Report 2009. As far as possible, the threats and their descriptions are consistent with those used in 2009.

Outlook Report 2014 (41 threats)	Outlook Report 2009 (41 threats)
Acid sulphate soils: Exposure of acid sulphate soils	*No equivalent threat*
Altered ocean currents: Climate change induced altered ocean currents	Climate change induced altered ocean currents
Altered weather patterns: Climate change effects on weather patterns (e.g. cyclones, wind, rainfall, air temperature)	Climate change induced altered cyclone activity
Artificial light: Artificial lighting including from resorts, industrial infrastructure, mainland beaches and coastlines, vessels and ships	*Not assessed*
Atmospheric pollution: Pollution of the atmosphere related to domestic, industrial and business activities in both the Region and adjacent areas. The contribution of gases such as carbon dioxide to climate change is not included as this is encompassed under threats such as sea temperature increase and ocean acidification.	*Not assessed*
Barriers to flow: Artificial barriers to riverine and estuarine flow (e.g. dams, weirs, breakwalls and gates)	Artificial barriers to riverine and estuarine flow (e.g. dams, weirs, breakwalls and gates)
Damage to reef structure: Physical damage to reef benthos (reef structure) through actions such as snorkelling, diving, anchoring and fishing, but not vessel grounding	Anchoring on coral by small vessels
	Physical impacts of snorkelling and diving activity
Damage to seafloor: Physical damage to non-reef benthos (seafloor) through actions such as trawling and anchoring	Physical impacts of fishing
Discarded catch: Immediate or post-release effects (such as death, injury, reduced reproductive success) on discarded species as a result of interactions with fishing gear. Does not include species of conservation concern.	Death of discarded species during fishing or collecting
Disposal of dredge material: Disposal and resuspension of dredge material	Dredging and dumping of spoil
Dredging: Dredging of the seafloor	
Exotic species: Introduced exotic species from aquaculture operations, hull fouling, ballast release, and release of aquarium specimens to the Region, plus the introduction of weeds, pests and feral animals to islands	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
Extraction from spawning aggregations: Retained take (extraction) of fish from unidentified or unprotected spawning aggregations	Fishing in unprotected fish spawning aggregations
Extraction of herbivores: Retained take (extraction) of herbivores (e.g. some fish, molluscs, dugongs, green turtles) through commercial and non-commercial uses	Extraction of herbivores by fishing
Extraction of particle feeders: Retained take (extraction) of particle feeders (filter feeders, detritivores) through commercial and non-commercial uses	Extraction of detritivores by fishing (e.g. prawns and sea cucumbers)
	Extraction of filter feeders by fishing (e.g. scallops)
Extraction of predators: Retained take (extraction) of predators (e.g. sharks, fish) through commercial and non-commercial uses	Extraction of lower order predators by fishing (e.g. coral trout)
	Extraction of top-order predators by fishing (e.g. sharks)

Outlook Report 2014 (41 threats)	Outlook Report 2009 (41 threats)
Grounding large vessel: Grounding of large vessels (>50m) including physical damage and the dislodging of antifoulants	Grounding of large vessels
Grounding small vessel: Grounding of small vessels (<50m) including physical damage and the dislodging of antifoulants	Grounding of small vessels
Illegal activities — other: Illegal activities such as entering a protected or restricted area, illegal release of industrial discharge, shipping outside of designated shipping areas	*Not assessed*
Illegal fishing and poaching: Illegal fishing, collecting and poaching	Illegal fishing or collecting (foreign or domestic)
	Poaching and illegal harvesting of species of conservation concern
Incidental catch of species of conservation concern: Immediate or post-release effects (such as death, injury, reduced reproductive success) of interactions of species of conservation concern with fishing gear	Incidental catch during fishing of species of conservation concern
Incompatible uses: Activities undertaken within the Region that disturb or exclude other users, such as recreational use in areas important for cultural activities	*Not assessed*
Marine debris: Manufactured material discarded, disposed of or abandoned in the marine and coastal environment (including discarded fishing gear and plastics)	Ingestion of or entanglement in marine debris causing death in species of conservation concern
Modifying coastal habitats: Clearing or modifying wetlands, mangroves and other coastal habitats	Clearing or modifying wetlands, mangroves and other coastal habitats
Noise pollution: Noise from human activities, both below and above water	*Not assessed*
Nutrient run-off: Nutrients from diffuse land-based run-off	Nutrients from catchment run-off
Ocean acidification: Decreasing pH of the Region's waters	Ocean acidification
Outbreak of crown-of-thorns starfish: Outbreak of crown-of-thorns starfish	Outbreak of crown-of-thorns starfish
Outbreak of disease: Outbreak of disease, both naturally occurring and introduced	Outbreak of coral disease
Outbreak of other species: Outbreak or bloom of naturally occurring species other than crown-of-thorns starfish	Outbreak of *Drupella* species
Pesticide run-off: Pesticides (including herbicides, insecticides, fungicides) from diffuse land-based run-off	Pesticides (including herbicides) from catchment run-off
Sea level rise: Rising sea level	Sea level rise
Sea temperature increase: Increasing sea temperature	Increasing sea temperature
Sediment run-off: Sediments from diffuse land-based run-off	Sediments from catchment run-off
Spill — large chemical: Chemical spill that triggers a national or regional response or is more than 10 tonnes	Large chemical spill
Spill — large oil: Oil spill that triggers a national or regional response or is more than 10 tonnes	Large oil spill
Spill — small: Chemical or oil spill that does not trigger a national or regional response and is less than 10 tonnes	Small chemical spill
	Small oil spill
Terrestrial discharge: Terrestrial point-source discharge including polluted water, sewage, wastewater and stormwater	*Not assessed*
Vessel strike: Death or injury to wildlife as a result of being struck by a vessel of any type or size	Boat strike leading to death in species of conservation concern
Vessel waste discharge: Waste discharge from a vessel (including sewage)	Waste discharge from vessels
Wildlife disturbance: Disturbance to wildlife including from snorkelling, diving, fish feeding, walking on islands and beaches, and the presence of boats; not including noise pollution	*Not assessed*

Appendix 6 Criteria for ranking likelihood and consequence to the Region's values

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. The likelihood and consequence of each predicted threat are ranked on the five-point scales described below.

Likelihood scale

Likelihood	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

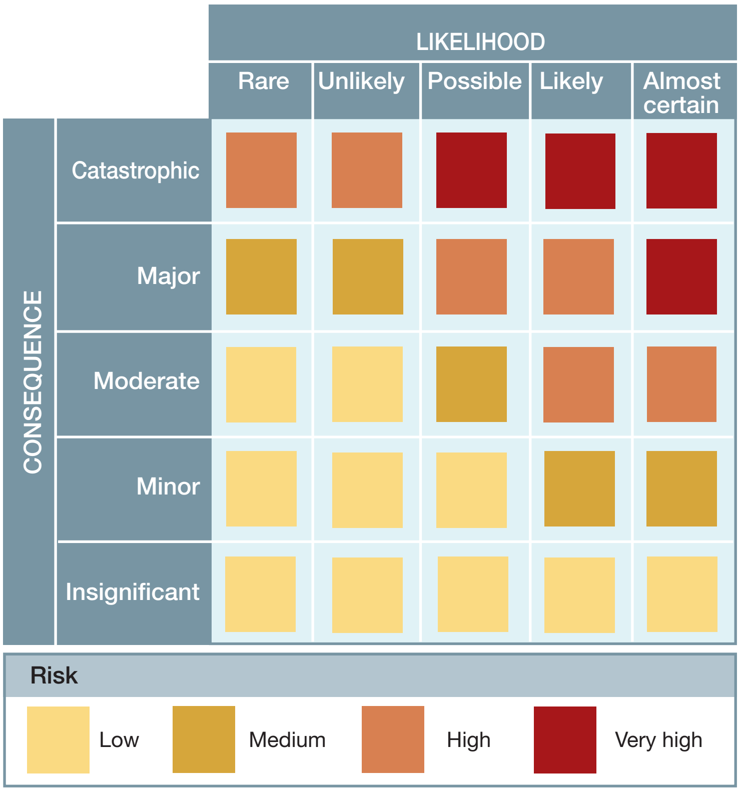
Consequence scale

Based on current management

Consequence	Ecosystem		Heritage
	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.		Impact is or has the potential to destroy a class or collection of heritage places on a large scale; or is clearly affecting, or would clearly affect, a range of heritage values over a wide area.
Major	Impact is, or would be, significant at a wider scale. Recovery periods of 10 to 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.	Impact is, or would, adversely affect the heritage values of a number of places; destroy individual heritage places of great significance; or significantly affect the heritage values over a wide area.
Moderate	Impact is, or would be, present at a wider scale, affecting some components of the ecosystem. Recovery periods of five to 10 years likely.	Impact is, or would be, serious and possibly irreversible over a small area. Recovery periods of 10 to 20 years likely.	Impact is, or would, affect individual heritage places or values of significance; or affect to some extent the heritage values at a wider scale.
Minor	Impact is, or would be, not discernible at a wider scale. Impact would not impair the overall condition of the ecosystem, or a 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 five to 10 years likely.	Impact is, or would, affect heritage places or values of local significance, but not at a wider scale. Impact would not impair the overall condition of the heritage values.
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.	No impact; or if impact is, or would be, present then only to the extent that it has no discernible effect on the heritage values; or positive impact.

Risk matrix legend

Likelihood and consequence are combined to determine risk level, in accordance with the Australian Standard for Risk Assessment (AS/NZS ISO 31000:2009).



		LIKELIHOOD				
		Rare	Unlikely	Possible	Likely	Almost certain
CONSEQUENCE	Catastrophic	🟧	🟧	🟥	🟥	🟥
	Major	🟫	🟫	🟧	🟧	🟥
	Moderate	🟨	🟨	🟫	🟧	🟧
	Minor	🟨	🟨	🟨	🟫	🟫
	Insignificant	🟨	🟨	🟨	🟨	🟨

Risk

🟨 Low 🟫 Medium 🟧 High 🟥 Very high

Appendix 7 Assessment of risks to the Region's values

Risks to the ecosystem

Threat	Likelihood	Consequence	Risk
Acid sulphate soils: The projected continuation of coastal development makes the future risk of exposure of potential acid sulphate soils possible. Once disturbed, if not treated, acidic water and heavy metals would continue to be released during rain events over decades if not longer, causing effects that may be irreversible in a small area.	Possible	Moderate	🟧
Altered ocean currents: A major change in oceanic currents of the Great Barrier Reef over the next 25 years is unlikely. However, an increase in the speed and southern extent of the East Australian Current has already been observed. Major changes to ocean currents would have widespread and potentially irreversible implications for biodiversity, including through implications for connectivity and recruitment.	Unlikely	Major	🟧
Altered weather patterns: A number of weather aspects are predicted to change as a result of climate change, including the frequency and intensity of cyclones, wind patterns, droughts and floods. For example, cyclones, a natural process in tropical regions, are predicted to become more severe, but less frequent, under current climate change scenarios. Severe cyclones have significant broadscale effects, with recovery times of at least 10 to 20 years. The broadening of this threat from just cyclones in the 2009 report, combined with effects of extreme weather experienced since that report and increased understanding, has increased the assessed risk of this threat.	Almost certain	Major	🟥
Artificial light: Growth in shipping and urban and industrial development is likely to increase the amount of artificial light. The main known risk of artificial light is its effect on turtle hatchlings' orientation. Other minor effects include effects on fish behaviour including on juvenile fish and the orientation of pelagic species around vessel lights, and potential effects on seabird behaviour.	Likely	Minor	🟧
Atmospheric pollution: Projected increases in urban and industrial development are likely to increase the local contribution of atmospheric pollution, including the potential for more frequent impacts from coal dust at loading ports. Atmospheric pollution may start to affect some values into the future; however, effects are expected to be only minor. The contribution of gases such as carbon dioxide to climate change is excluded here as this is encompassed under climate change related threats.	Possible	Minor	🟨
Barriers to flow: Artificial barriers in the catchment will continue to affect estuarine systems and connectivity. Improved understanding of the importance of connectivity between freshwater and marine systems has increased the consequence grading from Minor in the 2009 report to Moderate.	Almost certain	Moderate	🟫
Damage to reef structure: There is likely to be damage from anchors, diving and snorkelling throughout the year. If recreational vessel ownership continues to increase without a corresponding increase in supporting infrastructure and education, it is likely damage will increase.	Almost certain	Minor	🟧
Damage to seafloor: Current levels of trawling activity pose low risk to shallow (<90m) habitats at a Reef-wide scale, given existing protection through zoning, but local effects may be higher in intensely trawled areas. Consequences could increase if trawl fishing effort increases under more favourable economic conditions. Some areas are affected by ship anchoring.	Almost certain	Minor	🟧
Discarded catch: The discard of non-retained catch from fishing activities and the Queensland shark control program are predicted to occur continuously, with broadscale consequences for populations of species commonly caught. Although equipment such as bycatch reduction devices assist animals to escape from fishing gear, these and other interactions have associated risk of stress and injury (immediate and post-release effects).	Almost certain	Moderate	🟫

Risk

🟨 Low 🟧 Medium 🟫 High 🟥 Very high

Threat	Likelihood	Consequence	Risk
Disposal of dredge material: The disposal of dredge material is not continuous; however the frequency and volume of disposal and resuspension of dredge material (from both capital and maintenance dredging) is likely to increase with continued development and expansions of ports in the coming decade. The disposal and resuspension of sediment affects the condition of values at a local scale, adding further pressure to already declining inshore ecosystems. Uncertainty around the broader effects on the Region's values remains as detailed monitoring studies are lacking, although knowledge is improving.	Likely	Moderate	🟧
Dredging: Continued development and expansion of ports would require capital and ongoing maintenance dredging in coming decades. While maintenance dredging is expected to occur at least one or more times in a year, capital dredging is not expected to occur annually. The consequence for biodiversity within the footprint of the dredging site would be serious and possibly irreversible. While the likely amount of dredging has increased since the 2009 report, its relatively small footprint means it remains a medium risk to the Reef ecosystem.	Likely	Minor	🟨
Exotic species: Despite technological improvements for better detection, projected increases in shipping makes the transport and introduction of exotic species likely. The consequence would depend on the species but is likely to be serious in a small area such as adjacent to a marina or port.	Likely	Minor	🟨
Extraction from spawning aggregations: While a number of fish spawning aggregations are currently protected, some fishing effort is targeted at unprotected aggregations. Targeting spawning aggregations can have implications for recruitment and future population sizes of the species.	Likely	Moderate	🟧
Extraction of herbivores: Herbivorous fish and molluscs are not the primary target of most commercial and recreational fishing. The aquarium supply industry collects some species, a modest trochus harvest fishery is still in place and there is some spearfishing take. Current take of herbivorous fish is low and is unlikely to become very common. Traditional hunting of marine turtles and dugongs is currently managed in a number of areas under Traditional Use of Marine Resources Agreements, and there is the aim of implementing more agreements in the future. Although not continuous through the year, traditional hunting is likely to occur several times a year with potential effects at a small scale.	Likely	Minor	🟨
Extraction of particle feeders: Commercial, recreational and traditional fisheries that extract particle feeders are projected to continue, with the potential for the trawl fishery effort to increase under current management arrangements. The resilience and biology of these species generally allows them to be sustainably extracted if appropriately managed.	Almost certain	Minor	🟨
Extraction of predators: Trends in fishing effort are predicted to remain stable with effects at a wider level likely to require recovery periods of five to 10 years for most species. For top predators, some shark species extracted through the East Coast Inshore Fin Fish Fishery have life history traits that lend themselves to sustainable exploitation. Other top predators are slow breeding and extraction is likely to have at least moderate consequences. The network of no-take zones has already benefited populations of some predators. However, for larger, more mobile predators, benefits are limited. In the 2009 report the threat of extraction of lower order and top predators were considered separately, with the risks of Medium and Very high respectively.	Almost certain	Moderate	🟧
Grounding large vessel: Despite projected increases in shipping and reports of skipper fatigue, it is considered that current management of shipping, including the vessel traffic service, significantly reduces the likelihood of groundings. They are, therefore, not predicted to occur every year but possibly once in 10 years. Groundings can have severe impacts on biodiversity at the site with long recovery periods, and longer term and broader scale effects due to dispersal of antifouling paint.	Possible	Moderate	🟨
Grounding small vessel: There is likely to be small vessel groundings throughout the year and, under current management arrangements, this is likely to increase as recreational vessel use increases. These events are likely to be concentrated in areas of high use, but given the small size of most of the vessels, they are likely to have no discernible effect on the overall condition of ecosystem.	Almost certain	Insignificant	⬜
Illegal activities — other: Illegal activities such as entering a protected or restricted area, illegal release of industrial discharge, shipping outside designated shipping areas and operating without a permit are almost certain. The consequence of the activity will vary greatly depending on its type and location.	Almost certain	Minor	🟨

Threat	Likelihood	Consequence	Risk
Illegal fishing and poaching: Declining global fish stocks are likely to increase the demand on Australian fisheries. This, in turn, will increase the incentive for illegal foreign and domestic fishing activity. The consequence is likely to be major at a broad scale. Increasing illegal activity could have major consequences, particularly for sensitive areas and species. While the risk of illegal poaching of species such as dugong and turtles is likely to have decreased since the 2009 report (due to improved management arrangements), the risk associated with illegal fishing has increased — reflecting improved understanding of its serious effects.	Almost certain	Major	🟥
Incidental catch of species of conservation concern: Turtle excluder devices and bycatch reduction devices have significantly reduced the incidental catch of turtles in the trawl fishery. Death of discarded and incidentally caught species of conservation concern across all fisheries and the Queensland shark control program could have major consequences for a population.	Almost certain	Major	🟥
Incompatible uses: Only assessed for heritage values.			
Marine debris: Ocean currents transport debris around the world's oceans making the Reef vulnerable to debris from both local and more distant sources. Given the rapid increase in plastic production globally, the longevity of this material and the disposable nature of plastic items, plastic marine debris is likely to persist into the future and to be present at a broad scale within the Region. Given the increase in marine debris, the likelihood of this threat has increased since the assessment of Likely in 2009, increasing the risk rating from Medium to High.	Almost certain	Moderate	🟧
Modifying coastal habitats: The potential intensification of coastal agriculture and projected growth in urban and industrial development makes the likelihood of clearing and modifying supporting terrestrial habitats almost certain. However, understanding has increased about the need to ensure protection of coastal ecosystems and their ecosystem services. The consequence to the Region's values is likely to be major over a broad scale.	Almost certain	Major	🟥
Noise pollution: Projected increases in shipping and the continuation of increases in port development and recreational boat ownership mean underwater man-made noise is likely to be more or less continuous in the Region. Little is known about the effects of noise on the Region's species but evidence from elsewhere indicates that effects can be broadscale with serious consequences close to some sources. Improved understanding of its effects in the Region may change the future risk rating of this threat.	Almost certain	Minor	🟫
Nutrient run-off: Ongoing improvements in catchment management are likely to reduce nutrient loads in land-based run-off in the future. However, there is likely to be a significant lag time between changes in agricultural practice and measurable water quality improvements in the Region. It is projected that nutrients will continue to enter and remain in the Region well into the future with potentially major consequences on biodiversity.	Almost certain	Major	🟥
Ocean acidification: If trends in global carbon dioxide concentrations continue, concentrations could reach more than 450 parts per million within the next 25 years. Projections suggest the pH of waters of the Great Barrier Reef are almost certainly going to decrease. Regardless of the rate of change, recent evidence indicates that even relatively small changes in ocean pH reduce the capacity of corals and other calcifying organisms to build skeletons and shells, which in turn reduces their capacity to create habitat for reef biodiversity in general.	Almost certain	Catastrophic	🟥
Outbreak of crown-of-thorns starfish: Reductions in nutrient loads in land-based run-off may reduce the number of juvenile crown-of-thorns starfish that reach adulthood. Regardless, the presence of an active outbreak on the Reef at any given time is considered likely into the future, resulting in continued coral mortality. The cumulative effects of a range of impacts are severely compromising the ability of coral reefs to recover from outbreak events. Improved understanding of outbreaks, their frequency, causes and effects, has increased the grading of both likelihood and consequence since the 2009 report.	Almost certain	Major	🟥

Risk			
🟨 Low	🟫 Medium	🟧 High	🟥 Very high

Threat	Likelihood	Consequence	Risk
Outbreak of disease: The causes of disease are difficult to ascertain but are likely to be varied. For example, outbreaks of coral disease have been linked to increased sea temperature, making further outbreaks possible. Consequences will vary depending on the disease and duration of outbreak but could have moderate effects at a broad scale. The scope of the threat has been expanded from coral disease in the 2009 report to all disease. This, combined with improved understanding of distribution and causes, and a likely increase in susceptibility to disease as environmental condition deteriorates, has increased the assessed risk.	Likely	Moderate	🟧
Outbreak of other species: Changes in ecological processes as a result of other impacts may cause population explosions of some species. Considering outbreaks and blooms to date, the risk would be significant to a sensitive population or community at a local scale. However, there is a high level of uncertainty and the risk is likely to increase in the future. Only the threat of *Drupella* was considered in the 2009 report. An expansion to all species, combined with an overall decline in ecosystem condition, has increased the likelihood of an outbreak.	Likely	Minor	🟨
Pesticide run-off: Ongoing use of pesticides in the catchment means the Region will almost certainly experience pesticides from land-based run-off into the future. Continued progress towards targets for reducing pesticides in land-based run-off may reduce the consequences in the Region itself, but pesticides are expected to have extremely serious consequences to some estuarine, seagrass and freshwater ecosystems, resulting in flow-on impacts to biodiversity in the Region. Improved understanding of the distribution and effects of pesticides in the Region has decreased the consequence grading from that in the 2009 report; reducing the assessed risk.	Almost certain	Moderate	🟧
Sea level rise: Projected increases in sea level are almost certain into the future. This will have a noticeable effect on coastal and shallow-water habitats and species at a broad scale. Improved understanding since development of the 2009 report has changed the grading of likelihood and consequence; however, the overall risk remains unchanged.	Almost certain	Major	🟥
Sea temperature increase: The average annual sea surface temperature is almost certain to continue to rise. Regardless of the variation in climate scenarios, it is predicted that by 2035 the average sea surface temperature will be warmer than any previously recorded. Higher temperatures will affect the nature of the entire ecosystem over a broad scale.	Almost certain	Catastrophic	🟥
Sediment run-off: Although improved practices and restoration of riparian vegetation in many catchment areas has reduced sediment input, increased sediment loads will continue to be transported to and remain in the Region. Improvements in agricultural practices may take some time to become evident in water quality within the Region due to the lag time of sediments passing through the system and into sinks within the marine system. Projected increased rainfall variability may also contribute to sediment loads through the erosion of top soils during floods. Consequences of sedimentation for marine life will depend on the concentration and duration of exposure, however there are likely to be major effects on biodiversity. Improved understanding of the distribution and effects of increased sediments in the Region has resulted in an increase in the consequence assessment from Moderate to Major.	Almost certain	Major	🟥
Spill — large chemical: Although a large chemical spill is unlikely, the effects on biodiversity could be extremely serious and possibly irreversible at a local scale. Consequences would vary depending on the type and amount of spill and are considered major given current management and response plans.	Unlikely	Major	🟨
Spill — large oil: While shipping is projected to increase, recent improvements in management make the potential for a large oil spill unlikely. The physical smothering of plants and animals, combined with oil toxicity and its chemical reactions with water, mean a large spill is likely to have serious and persistent effects for several years.	Unlikely	Major	🟨
Spill — small: Small chemical and oil spills are likely to occur frequently in the Region. Projected increases in the number of ships and other vessels are likely to increase the likelihood in the future. There could be some effects on sensitive marine life in the area of the spill, with consequences depending on size and type of spill.	Almost certain	Insignificant	⬜
Terrestrial discharge: Projected increases in urban development will make discharges such as sewage and stormwater almost certain into the future. As regulations require sewage to be tertiary treated, sewage discharge is likely to be only a small component of the nutrient load entering the marine environment and have only minor effects. Discharges of wastewater from industrial development and mining that could have irreversible effects over a small area of the Region are possible, but are not expected to occur annually.	Almost certain	Minor	🟨

Threat	Likelihood	Consequence	Risk
Vessel strike: Continuing growth in shipping and recreational boating increases the potential for vessel strikes on wildlife. Surface-breathing animals are most at risk but the impact would not be discernible at the ecosystem level.	Likely	Minor	🟧
Vessel waste discharge: Increases in vessel traffic will mean there is likely to be more vessel-based waste discharge in the future. Effects on biodiversity are anticipated to be minor under current management arrangements.	Almost certain	Minor	🟧
Wildlife disturbance: Projected increases in population and a continuation of current increases in recreational vessel ownership, particularly in southern and central areas, are likely to lead to an increase in disturbance of wildlife from the presence of boats, snorkelling and diving activities and access to islands. The increase may cause some localised effects, for example on nesting seabirds.	Almost certain	Insignificant	🟨

Risks to heritage values

Threat	Likelihood	Consequence	Risk
Acid sulphate soils: The projected continuation of coastal development makes the future risk of exposure of potential acid sulphate soils possible. This may affect heritage places or values in a small area, including the subsistence lifestyles of local Traditional Owners.	Possible	Moderate	🟧
Altered ocean currents: A major change in oceanic currents of the Great Barrier Reef over the next few decades is unlikely, however minor changes have already been observed. Dynamic ocean currents are recognised as an ecological process that contributes to the Reef's outstanding universal value. Major changes would cause widespread and potentially irreversible effects on a wide range of the other attributes of outstanding universal value. It would have flow-on effects to Indigenous heritage values, especially for species that have cultural significance for customary practice, lore, storylines and songlines. Any changes in ocean currents are likely to have only minor effects on historic heritage values such as shipwrecks.	Unlikely	Major	🟧
Altered weather patterns: A number of weather aspects are predicted to change as a result of climate change. An increase in extreme weather events would have significant broadscale effects on some habitats and geomorphological features, especially coral reefs and seagrass meadows — two attributes that underpin much of the Reef's outstanding universal value. In addition, cyclones can affect culturally important sites (including sacred sites) and places of historic Indigenous significance. It is also likely that historic heritage sites and features such as shipwrecks, lighthouses, World War II sites and reefs of significance in the path of a severe cyclone will be damaged, potentially seriously.	Almost certain	Major	🟥
Artificial light: Growth in shipping and urban and industrial development is likely to increase the amount of artificial light. The main known risk of artificial light is its effect on turtle hatchlings' orientation in the nesting season (a recognised natural phenomenon in the world heritage listing). Reductions in turtle nesting success could have minor future flow-on effects on Indigenous cultural values such as totems and traditional hunting. Reduced dark sky area and lowered visibility of stars (from skyglow effects) may disrupt natural beauty and Indigenous storylines and songlines.	Likely	Minor	🟧
Atmospheric pollution: Atmospheric pollution may start to affect some heritage values into the future; however, effects are expected to be only minor. Corrosion, bio-degradation and soiling of materials used in built structures are some of the potential effects of atmospheric pollution. Natural beauty may also be affected by human-caused haze and deposition of particulate matter such as coal dust or terrigenous dust. The contribution of gases such as carbon dioxide to climate change is excluded here as this is encompassed under threats such as sea temperature increase.	Possible	Minor	🟨
Barriers to flow: Artificial barriers in the catchment will continue to affect estuarine systems and biological connectivity between freshwater and marine environments, affecting some species and processes that contribute to the Reef's outstanding universal value. There are also effects on the overall integrity of the world heritage property. In addition, these barriers may affect connectivity crucial to some totem species and could interrupt the flow of some storylines across the landscape.	Almost certain	Moderate	🟫

Risk

🟨 Low 🟧 Medium 🟫 High 🟥 Very high

Threat	Likelihood	Consequence	Risk
Damage to reef structure: There is likely to be damage to the reef structure from anchors, diving and snorkelling throughout the year. This could affect the natural underwater beauty in heavily visited locations. Damage to culturally significant features is also possible.	Almost certain	Minor	🟨
Damage to seafloor: There are likely to be local effects to the seafloor in intensely trawled areas and in ship anchorages. It is unlikely that any damage is significantly affecting the condition of the area's ecologically important interreefal areas — an attribute of the Reef's outstanding universal value. Depending on the location of the damage, culturally significant sites (including sacred sites, burial sites and sites that have storylines associated with them) could be affected. It is possible for undiscovered heritage sites (including wrecks) and features to be damaged. If an interaction occurs, the consequences are likely to be serious, or even irreversible.	Possible	Minor	🟨
Discarded catch: The discard of non-retained catch from fishing activities and the Queensland shark control program are predicted to occur continuously. While bycatch reduction devices and turtle excluder devices in the trawl fishery have reduced deaths of some culturally important species including marine turtles, risks remain for a range of others. If discarded catch floats or is washed ashore it can affect natural beauty.	Almost certain	Moderate	🟧
Disposal of dredge material: The disposal and resuspension of significant volumes of sediment could affect the condition of a number of attributes that contribute to the Reef's outstanding universal value by adding further pressure to already declining inshore ecosystems. Resuspended dredge material can also affect water clarity and therefore aesthetic beauty and ability to perform some cultural practices. Disposal of dredge material in areas with undiscovered heritage sites and features is possible but is not likely to affect heritage values over a wider area.	Likely	Moderate	🟧
Dredging: Continued development of ports is expected to require capital and ongoing maintenance dredging. The effect on the natural environment within the dredging site would be serious and possibly irreversible, but the activity's footprint is small. Assessment processes aim to avoid disturbance of heritage sites by dredging. However, some risk remains for unrecorded sites of Indigenous cultural significance — such as burial sites and sacred sites — and unrecorded historic heritage sites. While it is underway, dredging can also affect the scenic values of an area and increase noise levels.	Likely	Minor	🟨
Exotic species: Despite improvements in detection of exotic species, projected increases in shipping makes their introduction likely. The consequence would depend on the species and the heritage value affected, but there could be serious effects for attributes that contribute to the Reef's outstanding universal value and Indigenous heritage values in a local area.	Likely	Minor	🟨
Extraction from spawning aggregations: While a number of fish spawning aggregations are currently protected, some fishing effort is targeted at unprotected aggregations. Spawning aggregations are recognised as a natural phenomenon that contributes to the Reef's outstanding universal value. Effects on these aggregations will have consequences for the Indigenous heritage values connected to the species concerned.	Likely	Moderate	🟧
Extraction of herbivores: Herbivorous fish and molluscs are not the primary target of most commercial and recreational fishing. The aquarium supply industry collects some species, a modest trochus harvest fishery is still in place and there is some spearfishing take. Traditional hunting of marine turtles and dugongs is currently managed in a number of areas under Traditional Use of Marine Resources Agreements, and there is the aim of implementing more agreements in the future. This traditional use is likely to continue, is thought to be largely sustainable, and has a positive impact on Indigenous heritage values.	Likely	Insignificant	🟨
Extraction of particle feeders: Trends in fishing effort are predicted to remain stable. Given the important role of particle feeders in the ecosystem, there is likely to be some effects on attributes that contribute to outstanding universal value on a wide scale. There may be effects on cultural practices of Traditional Owners.	Almost certain	Minor	🟨
Extraction of predators: Trends in fishing effort are predicted to remain stable. Given the important role of predators in the ecosystem, there is likely to be some effects on attributes that contribute to outstanding universal value on a wide scale. There may be effects on cultural practices of Traditional Owners. In addition, some targeted predators are totems for many Traditional Owners. The exploitation of these animals and the localised impacts on populations will affect the cultural values of Traditional Owners with sea country estates.	Almost certain	Moderate	🟧

Threat	Likelihood	Consequence	Risk
Grounding large vessel: Current management of shipping significantly reduces the likelihood of groundings. They can have severe impacts on coral reef habitats at the site with long recovery periods. Many reefs have strong cultural value to Traditional Owners. Song and storylines are connected to them and in some cases they are sacred sites. The destruction and damage caused by a ship grounding could have significant and long-term effects on Indigenous heritage values. A ship grounding is likely to be rare at a site of historic significance, but it could have major consequences.	Possible	Moderate	🟧
Grounding small vessel: There is likely to be small vessel groundings throughout the year. These events are likely to be concentrated in areas of high use, but given the small size of most of the vessels, they are likely to have no discernible effect on the overall condition of natural heritage values. Should there be an accumulation of such groundings at a site of heritage significance, the local condition of associated values may be affected. If this occurred for multiple sites it would affect heritage values more broadly.	Almost certain	Insignificant	🟨
Illegal activities — other: Illegal activities such as entering a protected or restricted area, illegal release of industrial discharge, shipping outside designated shipping areas, vandalism at a heritage site and operating without a permit are almost certain. The likelihood of an illegal activity affecting a heritage value and the consequence of its effect will vary greatly depending on its type and location and the heritage values affected. The maintenance of traditional cultural ties can be affected by use of the Region which does not comply with management arrangements designed to support traditional use. Illegal activities at historic heritage sites such as the Commonwealth heritage-listed lightstations are more likely at sites without a permanent presence.	Almost certain	Minor	🟧
Illegal fishing and poaching: Illegal fishing is likely to increase in the future and its consequence for attributes of the Reef's outstanding universal value is likely to be major at a broad scale, including affecting the integrity of the world heritage property. Illegal poaching of species such as dugong and turtles is likely to have declined following implementation of improved management arrangements. Illegal fishing and poaching activities directly affect Traditional Owners' ability to practice customary lore, use their cultural tools and technology, and follow cultural observances.	Almost certain	Major	🟫
Incidental catch of species of conservation concern: There are immediate or post-release effects on some species of conservation concern, many of which contribute to the Reef's outstanding universal value. Many are also of cultural significance to Traditional Owners as either a food source, totem or for customary practice.	Almost certain	Major	🟫
Incompatible uses: The increasing volume and variety of uses occurring in the Region affects the capacity of Traditional Owners to continue their cultural practices and fulfil their customary responsibilities. Localised effects from commercial and recreational fishing can cause changes to customary practice if Traditional Owners have to fish or collect in non-traditional areas. Tourism-related and other structures can also affect the scenic beauty of an area.	Almost certain	Moderate	🟥
Marine debris: Marine debris affects many of the species that contribute to the outstanding universal value of the Great Barrier Reef as well as diminishing its natural beauty. Some marine animals and birds of Indigenous cultural significance can become entangled in or killed by marine debris. It also washes up in culturally important areas and sacred sites. On rare occasions, debris such as discarded fishing nets could become entangled on submerged historic sites, potentially degrading their heritage value.	Almost certain	Moderate	🟥
Modifying coastal habitats: Clearing and modifying supporting terrestrial habitats in the Great Barrier Reef catchment is almost certain. This is likely to continue to affect the outstanding universal value and integrity of the world heritage property, especially through diminishing the ecosystem services these habitats provide. Coastal habitat degradation may also diminish natural scenic values of the property. Even relatively small changes to land and seascapes have very significant consequences for Indigenous cultural values. Cultural observances, customs, storylines and songlines can be lost by changes to terrestrial habitats. In addition, without adequate consultation with Traditional Owners, reclamation on culturally significant sites would be possible and the values could be irretrievably compromised. Similarly, there is the potential that reclamation could occur on or close to an unrecorded site of historic heritage.	Almost certain	Major	🟫

Risk

🟨	Low	🟧	Medium	🟥	High	🟫	Very high

Threat	Likelihood	Consequence	Risk
Noise pollution: Little is known about the effects of noise on the Region's species, including to species which have particular cultural significance to Traditional Owners. Effects on auditory experiences may affect an area's natural beauty. Improved understanding of its effects may change the future risk rating of this threat.	Almost certain	Minor	🟨
Nutrient run-off: Ongoing improvements in catchment management are likely to reduce nutrient loads in land-based run-off in the future. However, there is likely to be a significant lag time between changes in agricultural practice and measurable water quality improvements in the Region. The widespread effects of increased nutrients, especially in coastal waters, diminish many components of the Reef's outstanding universal value. Such declines in the environment will, in turn, affect the Indigenous heritage values of the Region. Nutrients are unlikely to be affecting historic heritage values, other than contributing to declines in the health of reefs of historic significance.	Almost certain	Major	🟥
Ocean acidification: Projections suggest the pH of waters of the Great Barrier Reef is almost certainly going to decrease. Even relatively small changes in ocean acidity will affect coral reef habitats and many reef species. Because coral reefs are one of the fundamental attributes that make up the Reef's outstanding universal value (recognised as a habitat and a geological feature, for their natural beauty and for the phenomenon of coral spawning) this threat could have major consequences for world heritage values. The decline in environmental condition will have consequent effects on Indigenous heritage values. Ocean acidification could have an effect on shipwrecks of historic significance, but it is likely to be insignificant.	Almost certain	Catastrophic	🟥
Outbreak of crown-of-thorns starfish: The likely almost continual presence of an active crown-of-thorns starfish outbreak on the Reef will severely compromise the ability of coral reefs to recover after disturbances. As with other threats that are likely to seriously affect coral reefs, continued outbreaks will seriously diminish the outstanding universal value of the Reef. The decline in coral reef health will have consequent effects on Indigenous heritage values.	Almost certain	Major	🟥
Outbreak of disease: The likelihood and consequences to the natural environment of a disease outbreak will vary, however overall susceptibility to disease is likely to increase as the Reef's condition deteriorates. Widespread disease outbreaks would diminish the Reef's outstanding universal value. Outbreaks of disease such as in corals and turtles can diminish Indigenous cultural values through affecting cultural practices, customs and lore. Outbreaks that may seem moderate at a broad scale could have significant impacts at a smaller, more local level.	Likely	Moderate	🟧
Outbreak of other species: Changes in ecological processes as a result of other impacts may cause outbreaks of some naturally occurring species. Little is known of the potential effects of outbreaks or blooms of other species to Indigenous cultural values, but any declines in ecosystem health will have consequent effects on Indigenous heritage values.	Likely	Minor	🟨
Pesticide run-off: Ongoing use of pesticides in the catchment means the Region will almost certainly experience pesticides from land-based run-off into the future. The effects of pesticides on some estuarine, seagrass and freshwater ecosystems will diminish some components of the Reef's outstanding universal value. Such declines in the ecosystem will, in turn, affect the Indigenous heritage values of the Region. Bioaccumulation of toxic components of pesticides will have additional adverse effects if this makes some species unsafe for consumption as part of cultural practices.	Almost certain	Moderate	🟧
Sea level rise: The almost certain increase in sea level will have noticeable effects on coastal and shallow-water habitats and species over a broad scale, in particular affecting phenomena of outstanding universal value such as turtle and seabird nesting. Rising sea level could also affect coastal and shallow-water Indigenous heritage sites, as well as cause changes to custom. Loss of access to fish traps, burial sites (which may be in coastal sand dunes), or rock art located in beach caves will have adverse consequences to cultural practices. Rising sea level is also likely to have some minor effects on coastal and shallow-water historic heritage sites.	Almost certain	Major	🟥
Sea temperature increase: The average annual sea surface temperature is almost certain to continue to rise, affecting almost all attributes of outstanding universal value over a broad scale, from its ecological processes and key habitats and species to its natural beauty and natural phenomena. Such declines in the environment will, in turn, affect the Indigenous heritage values of the Region. On a smaller scale, increased sea temperatures could accelerate the natural degradation of historic heritage sites.	Almost certain	Catastrophic	🟥

Threat	Likelihood	Consequence	Risk
Sediment run-off: Although improved practices and vegetation restoration has reduced sediment input, elevated loads will continue to be transported to and remain in the Region. The widespread effects of increased sediments, especially in coastal waters, diminish many attributes of the Reef's outstanding universal value, including habitats, species, ecological processes and geomorphological processes. Increases in turbidity also decrease the underwater natural beauty of the world heritage property. Declines in the environment caused by increased sediments will, in turn, affect the Indigenous heritage values of the Region. Increased sediments are unlikely to significantly affect historic heritage values.	Almost certain	Major	🟥
Spill — large chemical: A large chemical spill is unlikely, and the consequences would vary depending on the type and amount of spill. A large chemical spill that affects biodiversity would have flow-on effects to the Reef's outstanding universal value and to the cultural values of Traditional Owners. A spill that had severe effects on the local environment could have extremely serious and possibly irreversible effects on Indigenous cultural practice, observances, story and song lines and places of cultural significance at a local scale. In addition, a large chemical spill close to an historic heritage site could present a serious risk to its values.	Unlikely	Major	🟫
Spill — large oil: A large oil spill is unlikely, however the physical smothering of plants and animals, combined with oil toxicity and its chemical reactions with water, mean a large spill would likely have serious and persistent effects on some attributes of outstanding universal value, such as coral reefs, seabirds and turtles. It would also affect the natural beauty of the spill area in the short term. Any impacts on animals or land and seascapes would have a similarly negative effect on Indigenous heritage values. It is expected that a large spill would rarely affect a historic site or feature.	Unlikely	Major	🟫
Spill — small: Small chemical and oil spills are likely to occur frequently in the Region, with consequences depending on size and type of spill. There is unlikely to be serious consequences to the Region's heritage values from small chemical and oil spills.	Almost certain	Insignificant	🟨
Terrestrial discharge: Projected increases in urban and industrial development will make point-source discharges, such as polluted water, sewage, wastewater and stormwater, almost certain into the future. While the discharges are unlikely to affect the outstanding universal value of the Reef, there may be localised effects on some Indigenous heritage values. For example, elevated concentrations of heavy metals in culturally significant species such as dugong and turtle or concentrations of bacteria unsafe for human immersion could place cultural values and practices at further risk.	Almost certain	Minor	🟫
Vessel strike: Continuing growth in shipping and recreational boating increases the potential for vessel strikes on wildlife. Some of the species that contribute strongly to the Reef's outstanding universal value, such as dugongs, turtles and whales, are most at risk. As these species also have cultural significance for Traditional Owners, there is likely to be local effects on Indigenous cultural heritage.	Likely	Minor	🟫
Vessel waste discharge: Increases in vessel traffic will mean there is likely to be more vessel-based waste discharge in the future. The likely minor effects on the natural environment will have flow-on effects on Indigenous heritage values.	Almost certain	Minor	🟫
Wildlife disturbance: Projected increases in population and a continuation of current increases in recreational vessel ownership, are likely to lead to an increase in disturbance of wildlife. The increase could cause localised effects on attributes of outstanding universal value such as the natural phenomena of seabird and turtle nesting. Changes to animal behaviour caused by the presence of boats or people can change the nature of Traditional Owner customary practice and change storylines.	Almost certain	Minor	🟫

Risk			
🟨 Low	🟫 Medium	🟧 High	🟥 Very high

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